

BIOLOGY, SPATIAL DISTRIBUTION, AND CONTROL OF
Oligonychus (Oligonychus) ilicis (McGregor)
(Acarina: Tetranychidae) on
Ilex crenata 'Hetzii'

BY

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Abstract of Dissertation Presented to the
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BIOLOGY, SPATIAL DISTRIBUTION, AND CONTROL OF
Oligonychus (Oligonychus) ilicis (McGregor)
(Acarina: Tetranychidae) on
Ilex crenata 'Hetzii'

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Studies were conducted to determine the temperature effects on the development and reproduction of the southern red mite, Oligonychus (Oligonychus) ilicis (McGregor) reared on holly, Ilex crenata 'Hetzii,' to ascertain the mites' spatial distribution on field grown I. crenata, and to evaluate selected acaricides for residual control of O. (O.) ilicis.

Southern red mites completed development through all stages under constant temperatures ranging from 15.5 to 35°C. In general, developmental times of all stages and adult longevity decreased as temperatures increased. Males developed more rapidly than females at all temperatures except 26.5°C. The developmental curves for all stages were cubic. Mortality curves for males and females dropped

more abruptly as temperature increased. The survival rate of O. (O.) ilicis was greatest for eggs, and the highest mortality occurred in the larval stage. The net reproductive rate was highest (7.0961) at 26.5°C. The mean generation time was shortest (2.5695) at 35° and longest (7.3119) at 21°C. The intrinsic rate of natural increase was greatest (0.4694) at 26.5°C. The number of degree days required for the development of each immature stage at 6 different temperatures indicated that the egg stage required the greatest amount of heat.

Southern red mites were found predominantly on the under surface of I. crenata. The mean number of mites in the upper portion of the plants differed significantly at the 1% level from the means for the lower and middle heights. Means for eggs did not differ with regard to height. Significantly more eggs and mites were located in the inner zone of the plants. More eggs and mites were found in the north and south quadrants than in the east and west quadrants. The optimum sampling location on I. crenata appeared to be in the inner zone and at the upper height in either the north or south quadrants.

Hexakis (H), propargite (P), dicofol (D), and naled (N) and combinations of these 4 acaricides were evaluated for control of O. (O.) ilicis on field grown holly. Hexakis provided the best control after three weeks of the compounds sprayed singly. Combinations of compounds offering equally good residual action were H+P, H+D, H+P+D, H+P, N, P+D+N, and H+P+D+N.

GENERAL INTRODUCTION

The southern red mite, Oligonychus (Oligonychus) ilicis (McGregor), was first described by McGregor in 1917 as Tetranychus ilicis. The original specimens were taken from American holly, Ilex opaca Ait., in Batesburg, South Carolina (McGregor, 1917). Oligonychus (O.) ilicis attacks an array of ornamental shrubs, trees and economically important crops, producing a bronzing and browning or graying of the upper leaf surface. This mite has been collected from dogwood, Cornus florida L., in Ohio (Miller, 1925), raspberries in Michigan (McGregor, 1931; Hutson, 1933), and sycamore, Platanus sp., and walnut, Juglans sp., in California (Keifer, 1935; Smith, 1939). The southern red mite is a pest of conifers in eastern and of azalea and camellia in the southeastern United States. It attacks cranberries in Massachusetts, coffee in Brazil, and tea, rice, laurel, holly, and boxwood in Japan (Jeppson et al., 1975; Ehara, 1963). Infestations have also been reported on camphor, eucalyptus, pear, quince, loquat, spruce, and oak (Jeppson, et al., 1975). The southern red mite has been recorded from more than 25 host plants in Florida (Division of Plant Industry Records). It is particularly a pest of azaleas, camellias, and holly.

For several years this mite has been an economically important pest of field grown holly, Ilex crenata 'Hetzii.' Little was known about the pest's biology or spatial distribution on this host. Attempts to control the mite chemically were costly and not very successful. The objectives of this study were to determine the effects of temperature on the southern red mite's development and fecundity, to ascertain its spatial distribution on holly, and to evaluate selected acaricides and combinations for residual control.

TEMPERATURE EFFECTS ON THE DEVELOPMENT AND REPRODUCTION
OF THE SOUTHERN RED MITE, Oligonychus (Oligonychus)
ilicis (McGregor) REARED ON Ilex crenata 'Hetzii'

Introduction

The southern red mite, Oligonychus (Oligonychus) ilicis (McGregor), is a pest of woody ornamental plants feeding primarily on foliage. Oligonychus (O.) ilicis has been observed in the field in greatest numbers during the fall and winter months. Populations increase with the onset of cooler weather in late October and early November and remain at high levels until May. For several years heavy infestations of this mite on nursery grown Ilex crenata 'Hetzii' have resulted in unsightly plants, severe leaf drop, and loss of sales for the grower.

Calsa and Sauer (1952) reported the life history of O. (O.) ilicis on coffee in Brazil, but comparable data do not exist for this mite on ornamentals in the United States. Detailed studies of the pest's life history are needed to develop effective control measures. The objectives of this research were to examine the influence of temperature on the mite's developmental time, fecundity, and mortality, to construct life tables, and to determine the intrinsic rate of increase and the number of degree days required for development.

Literature Review

The vital importance of temperature to development of tetranychid mite populations has long been recognized. A number of studies have been conducted to determine the influence of temperature on life history parameters of economically important members of the genus Oligonychus.

The tea red spider mite, O. (O.) coffeae (Nietner), has been a pest of tea, Camellia sinensis, in India since the early days of tea cultivation. Temperature and humidity were limiting factors in this mite's development. Oviposition usually began within 24 hours after emergence of the adult female from March to June, but in cold weather the preoviposition period lasted 2 or 3 days. Females usually laid 4 to 6 eggs per day with 10 being the maximum. The maximum number of eggs laid by a female was 137 with an average of 91 during May. Incubation time ranged from 4 or 5 days in September (mean temperature = 27°C) to as long as 13 days in January (mean temperature = 16°C). Length of the larval stage ranged from 1 day in June (mean temperature = 29°C) to 3 days in November (mean temperature = 21°C). The total duration of larval and nymphal stages ranged from 11 days in February to 6 days in June. The maximum longevity for females was 29 days with an average of 24 days in April. Males died within 4 or 5 days under field conditions, but if unmated, they lived longer (maximum of 12 days). Outdoors in May and June the

life cycle was completed in 9 to 12 days, while in cold weather 28 days were required for life cycle completion.

In another study by Das and Das (1967), O. (O.) coffeae was reared at five constant temperatures. Each quantity measured varied inversely with temperature with a relative humidity of 75 to 80%. Preovipositional period ranged from 2 days at 20° to 1 day at 32°C. Oviposition ranged from 31 days at 20° with a mean of 107 eggs produced per female to 6 days at 32°C with a mean of 12 eggs per female. Incubation ranged from a mean of 11 days at 20° to 4 days at 32°C. The range for larval development time was 3 days at 20° to 2 days at 30°C. Larval mortality was high at 32°C. The duration of the protonymphal stage ranged from 3 days at 20° to 2 days at 32°C. Deutonymphs required 3 days at 20° to 2 at 30°C. The total life cycle from egg to adult averaged 20 days at 20°, 12 at 25°, 11 at 27°, and 9 at 30°C. Das and Das (1967) also found that no eggs hatched at 34°C irrespective of humidity. At 33°C a small percentage of eggs hatched at relative humidities of 72 to 100%, but none hatched at lower humidities. Optimum conditions required for hatching (90% or more hatch) were found to be within the ranges of 20 to 30°C and 49 to 94% relative humidity.

Hu and Wang (1965) studied the tea red spider in Taiwan, and their findings generally corresponded with those of Das (1959) in India, but developmental rates of different stages were slightly faster in Taiwan.

Banerjee (1975) determined development parameters and intrinsic rate of increase for O. (O.) coffeae reared in the laboratory at 30°C and 85% relative humidity on Assam and China tea varieties. Female survival and age-specific fertility decreased in a near linear form as temperature increased. The net reproductive rate was determined to be 14.3 for China variety and 11.5 for Assam variety. For China variety the intrinsic rate of increase was 0.81 and for Assam variety, 0.72. The finite rate of increase was 6.5 for China tea and 5.2 for Assam tea. Generation length was 3.3 and 3.4 for China and Assam varieties, respectively. Capacity for increase was 0.60 for China tea and 0.85 for Assam.

Calsa and Sauer (1952) reported on the biology of O. (O.) ilicis reared on coffee. The southern red mite appeared year round on coffee plants in Brazil. Greatest damage was inflicted on coffee plants during the dry winter season in higher, drier areas of the country. Preoviposition averaged 3 days and females usually deposited 10 to 15 eggs with a maximum of 24 eggs recorded for one female. Ovipositing females averaged ca 2 eggs per 12 hour period with a range of 1 to 3 eggs per 12 hours. The oviposition period lasted 3 days, and adult females lived for 15 days. Incubation required 6 to 10 days with an average of 7 days at 22°C. At 23°C development from larva to adult required 5 to 10 days with an average of 7 days. The length of the entire life cycle ranged from 11 to 17

days with an average of 14 days. The sex ratio was 1:4 (males to females).

In Massachusetts, hatching of overwintering eggs of O. (O.) ilicis occurred in late April and early May (Matthysse and Naegele, 1952). Peak population levels were reached in June at about the time migration to new growth occurred. The population declined in late June and July and again increased in September when large numbers of overwintering eggs were deposited.

The biology of O. (O.) mangiferus (Rahman and Sapra) was studied in Egypt under natural climatic conditions by Zaher and Shehata (1971). The number of eggs deposited per female varied according to the seasons averaging 24, 30, 34, and 20 eggs during spring, summer, autumn, and winter, respectively. Oviposition duration ranged from 9 days in summer to 17 days in winter. The average duration of immature stages ranged from 5 days in summer to 17 days in winter. The generation time ranged from 10 days at an average temperature of 30°C in summer to 42 days at an average temperature of 16°C in winter. Temperature had a highly significant correlation with the generation period.

The biology of the spruce spider mite, O. (O.) ununguis (Jacobi), has been studied by Garman (1923), Löyttyniemi (1970), and Akita (1971). This species overwintered as eggs laid near the base of needles and in other protected areas. Eggs hatched in April, and mites infested trees until fall. The preoviposition period ranged from 1 to 4

days. Incubation varied from 5 days at 27 to 33°C to 13 days at 17°C, averaging about 11 days at 21°C. The time for development of larva to adult required about 5 days at 27 to 33°C or 13 days at 17°C. At 21°C this period lasted 9 days.

Löyttyniemi (1970) studied the spruce spider mite in the field and in the laboratory and found that its eggs showed development at very low temperatures (0 to 8°C). At 30°C no development occurred in the egg. At 10, 15, 20, 25, and 30°C the generation times for O. (O.) ununguis were 53, 26, 18, 14, and 12 days, respectively. Degree days required for a generation were 265, 260, 270, 280, and 300 for 10, 15, 20, 25, and 30°C, respectively.

Akita (1971) observed six or more generations a year of O. (O.) ununguis on Todo fir in Japan. The first larvae emerged in May. The threshold for development was calculated to be ca 7°C, and the total effective temperature of winter eggs was 129 degree days. In an insectary study, the development speeds of each stage varied with the generation or the season and became shorter with rising temperatures. Under controlled temperatures, as developmental speed and fecundity increased with temperature, oviposition period and female survival decreased.

The biology of the avocado red mite, O. (O.) yothersi (McGregor), was reported by Ebeling (1959). Incubation of eggs required from 7 to 11 days. The larval, protonymphal,

and deutonymphal stages required about 3 days each. The average life cycle was 14 days.

The avocado brown mite, O. (O.) punicae (Hirst), exhibited developmental times for each stage which were not significantly different from the avocado red mite, O. (O.) yothersi, under similar temperatures (Ebeling, 1959). In the summer there may be two complete generations in a month. Seven days were required to complete a generation at a constant temperature of 25°C. At a constant temperature of 33°C all stages died, including eggs (McGregor, 1941). McMurtry and Johnson (1966) reported on the developmental times of O. (O.) punicae at 22°C and 40 to 50% relative humidity. The preoviposition period lasted 2 days. The egg stage required 8 days. Females produced ca 3 eggs per female per day on mature undamaged leaves. One generation (egg to egg) required 15 to 16 days.

Butler and Abid (1965) studied the biology of O. (Homonychus) platani (McGregor), a serious pest of Pyracantha spp. in Arizona. Under greenhouse conditions during June, July, and August, the time required for development from egg to adult was 13, 12, and 10 days, respectively. In June each individual stage required more time for development than in July or August. Under constant temperatures of 15, 24, and 29 ±2°C full development required 32 days, 11 days, and 9 days, respectively. The duration of all life stages decreased as temperature increased. Longevity of adult females was 7 days at 29°,

17 days at 24° and 21 days at 15°C. The preoviposition period was 1 to 2 days. Oviposition ceased 3 to 4 days before death. The average number of eggs laid by fertilized females during their life span was 24 under greenhouse conditions. Under constant temperatures, the average number of eggs laid per female was 9 at 29°, 35 at 24°, and 17 at 15°C.

Gupta et al. (1975) studied the sugarcane red spider mite, O. (Reckieella) indicus, at five constant temperatures on three hosts, sugarcane (Saccharum officinarum Linn.), sorghum (Sorghum vulgare Pers.), and maize (Zea mays Linn.). Minimum time for completion of the life cycle and highest fecundity were recorded for mites reared on maize at 30°C. Preoviposition was shorter at higher temperatures (33 and 35°C, where it varied from 0.2 to 0.7 days) and longer at lower temperatures (25 and 28°C, where it varied from 0.9 to 1.9 days) irrespective of food. Maximum fecundity per female per day was 18 eggs on maize at 30°C, and the minimum per day was zero. Maximum eggs produced in an entire life cycle was 193 on sorghum at 33°C and a minimum of 4 on maize at 35 and 28°C. Oviposition and postoviposition periods were shorter at higher temperatures. Fertilized females exhibited maximum fecundity (73) on sorghum at 30°C and a minimum fecundity (10) on sugarcane at 28°C. Incubation was shortest (2 days) on maize at 35°C and longest (5 days) on sorghum at 25°C. The larval period ranged from 1 day on maize at 35°C to 3 days on sugarcane at 25°C.

The duration of the protonymphal period was generally shorter at 33 and 35°C and longer at lower temperatures. The duration of the deutonymphal period was shortest (1 day) on maize at 35°C and longest (3 days) on maize at 25°C. At 30, 33, and 35°C the life cycle was completed most rapidly on maize, but at 25 and 28°C, mites developed most rapidly on sugarcane. Minimum time for completion of the life cycle was 4 days on maize at 35°C, and the maximum was 12 days on sorghum at 25°C. Adult longevity was influenced more by the food provided than the temperature. Longevity ranged from 6 days at 35°C on maize to 19 days on sugarcane at 28°C.

The paddy mite, O. (R.) oryzae (Hirst), was found by Misra and Israel (1968) to be prolific under conditions of high temperature and humidity. Heavy pest populations occurred in September and October when the relative humidity was 95 and 94% and the average temperatures 27 and 28°C, respectively. Paddy mites were present in small numbers in December and January when the relative humidity was 91 and 95% and the average temperatures were 20 and 21°C, respectively. The life cycle was completed in 6 to 8 days in August and September but lasted as long as 19 days in December. Preoviposition time varied from 1 to 3 days, with an average of 1 day. The oviposition period ranged from 6 to 12 days, averaging 9 days. Females usually laid 2 to 3 eggs per day, with a maximum of 5. The maximum eggs produced by a female in her lifetime was 21. The incubation

period was 4 or 5 days in August and September but as long as 9 days during cold weather. Postoviposition varied from 1 to 3 days, with an average of 1 day. The average larval, protonymphal, and deutonymphal periods were 2 to 3, 1-1/2 to 2, and 2 to 3 days, respectively. Adult female longevity ranged from 7 to 13 days, averaging 11 days. Males generally lived for 5 to 6 days, but if unmated, they lived for 9 days.

Several researchers have studied the biology of the Banks grass mite, O. (R.) pratensis (Banks). Malcolm (1955) investigated the biology of this mite on barley under seasonal conditions. Incubation time ranged from an average of 22 days for the first generation in April to 6 days for the third generation. The length of the larval stage for the 7 generations observed ranged from a minimum of 2 days for both sexes to a maximum of 16 days for males and 17 days for females. Total developmental time for the protonymphs ranged from 1 to 13 days for both sexes. The time for total development for deutonymphs ranged from 1 to 14 days for males and 2 to 18 days for females. The time required for development from hatching to adult emergence ranged from 5 to 32 days for males and from 5 to 37 days for females. The preovipositional period ranged from 1 day in the second generation to 4 days in the sixth generation. The averages of the ovipositional periods for all generations ranged from 11 days in the second generation to 48 days in the sixth generation. The average number of eggs

per female ranged from 51 in the fifth generation to 76 eggs in the fourth generation. The average longevity for females ranged from 14 to 37 days. Some males reached an advanced age with the longest recorded time being 95 days in the third generation.

Elmer (1965) briefly described the biology of the Banks grass mite, O. (R.) pratensis, on dates. At room temperature on green dates, egg production varied from 10 to 21 eggs per female. The length of the life cycle varied from 7 to 15 days.

Feese and Wilde (1977) investigated the effects of temperature, relative humidity, plant growth stage, and host plant water stress on the development of the Banks grass mite. Mites developed most rapidly when temperatures were high. The incubation period ranged from 10 days at 16° to 3 days at 32°C. Other developmental stages were not discussed. The effects of relative humidity were significant. The percentage survival of mites was significantly greater (5% level) on silking corn than on seedling corn, and significantly more eggs were laid on silking than seedling corn, which may be due to the increased nutritional level of the leaves in the silking stage. Fecundity was not significantly different (5% level) among 3 irrigation treatments.

Tan and Ward (1977) reared the Banks grass mite in the laboratory on sorghum (DeKalb F-65) at 24 to 35°C, 25% relative humidity, and 14 or more hours of light. Life

cycle length (egg to adult) was 7 to 13 days with total longevity varying from 14 to 36 days. Six to 14 eggs were laid per female per day with maximal oviposition on the sixth day of adulthood (12 eggs per female). The lengths of all life stages and survival rates were lower in this study than in the study by Malcolm (1955). Tan and Ward (1977) constructed a life table and found from the trend index and the generation survival rate that more than a 70-fold increase in population could occur within one generation.

Methods and Materials

Oligonychus (O.) ilicis (McGregor) were collected in 1979 from field grown holly, I. crenata, at Blair Nursery near Macclenny, Florida. Infested plant material was taken to Gainesville to the laboratory where adult female mites were transferred with a 00 camel hair brush to holly leaves free of other mites and eggs. Five leaves, each with 5 mites, were placed on absorbent cotton in open 90 mm diameter petri dishes. The cotton was saturated with tap water to keep the leaves fresh and to retard mite escape. The petri dishes were kept at 26.5°C, and female mites were allowed to oviposit for 18 hours before they were removed from the leaves. Approximately 10 of these petri dishes for each temperature were transferred to environmental chambers set at 13.0, 14.5, 15.5, 21.0, 26.5, 29.5, 32.0, 35.0, and 37.5 ±1°C with a 12:12 L:D photoperiod. The environmental chambers were illuminated with fluorescent tubes, and mites

received a light intensity ranging from 63 to 350 ft-c. (Uniform light intensity could not be achieved because of differences in the lighting capacity of the models of environmental chambers used.) Humidity within the chambers was not controlled.

After its emergence from the egg, each larval mite was isolated on a holly leaf. Five leaves were placed under-surface up on cotton in petri dishes. Each isolated mite was transferred to a newly excised holly leaf every 4 to 5 days to avoid the effects of leaf deterioration.

To determine how frequently mites should be observed to best reflect actual developmental times, data for 21.0° and 26.5°C collected in 1978 at 6 hour intervals were analyzed on a quarter-day, half-day, and whole-day basis using a one-way analysis of variance and Duncan's multiple range test. Significant differences were found between quarter-days and whole-days but not between quarter-days and half-days. Therefore, all observations in 1979 were made every 12 hours (half-day) to determine time of egg hatch, individual growth rate, fecundity, and mortality. Exuviae were removed after each molt. Stage-specific life tables were developed from the data collected. The intrinsic rate of natural increase, the net reproductive rate, the mean generation time, and the number of degree days required for development of each stage at each temperature were calculated.

Results and Discussion

Southern red mites were able to complete development under constant temperatures ranging from 15.5 to 35°C. Incubation time of eggs decreased as temperatures increased except at 35°C where a slight increase was noted (Fig. 1). The developmental times of larvae, protonymphs, and deutonymphs followed a similar pattern and were all shorter than adult longevity at each temperature. As temperatures increased, the larvae exhibited a decrease in developmental time from 15.5 to 35°C with a slight increase in developmental time at 37.5°C. Protonymph developmental times decreased from 15.5 to 29.5°C, increased slightly at 32°C, and dropped again at 35°C. The deutonymphs' developmental time decreased from 15.5 to 32°C, followed by a slight increase at 35°C. Adult longevity had an erratic pattern but showed a general downward trend with increasing temperature. Maximum longevity was observed at 21°C and minimum longevity at 35°C. Mites could not complete development through all stages below 15.5 or above 35°C.

To determine the lowest threshold for completion of the life cycle, 142 and 128 eggs were held in constant temperature chambers for 45 days at 12.5 ± 1 and $14.1 \pm 1^\circ\text{C}$, respectively. None of the eggs hatched under either temperature regime. The eggs held 45 days at 12.5°C were transferred to a 26.5°C chamber, and 47 of the 142 eggs hatched in a mean time of 7.1 ± 0.1 days. Six larvae survived, with an

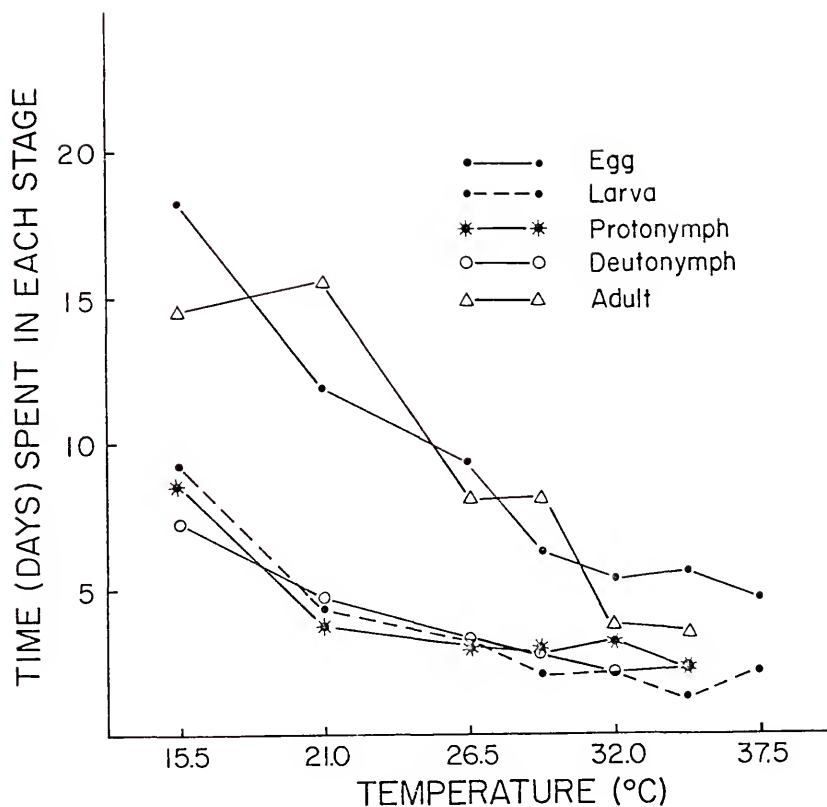


Fig. 1. Mean developmental times for immature stages and adult longevity of *Oligonychus (Oligonychus) ilicis* (McGregor) reared at 7 constant temperatures in 1979.

average developmental time of 3.3 ± 0.6 days. The duration of the protonymphal stage for 4 mites was 3.3 ± 0.4 days. One female deutonymph had a developmental time of 3 days. This female survived to adulthood and lived for 2 days, but produced no eggs. The mean incubation time of 7.1 ± 0.1 was less than that for eggs laid and held continuously at 26.5°C (Fig. 1) indicating that some development occurred at 12.5°C . The values for other immature developmental times were comparable for those of immature stages reared at 26.5°C from egg to adult.

Forty-two eggs were placed in a 37.5°C chamber, and incubation required an average of 4.6 ± 0.4 days. Mean duration of the larval stage was greater at 37.5 than at 35°C . Only three larvae survived; all of these died as deutonymphs.

Other members of the genus Oligonychus exhibited shorter developmental times than O. (O.) ilicis. Developmental times for immature O. (R.) indicus were shorter than those of O. (O.) ilicis at comparable temperatures, but the longevity of O. (R.) indicus adults was greater than that of O. (O.) ilicis adults (Gupta et al., 1975). Oligonychus (H.) platani (Butler and Abid, 1965) exhibited shorter developmental times for immature stages than O. (O.) ilicis at approximately 15.5°C . At 29.5°C O. (H.) platani had a more rapid incubation, protonymphal, and deutonymphal period but a slower larval development time. Oligonychus (O.) yothersi required 7 days to complete a generation at 25°C .

Oligonychus (O.) ilicis required considerably longer at 26.5°C. At a constant temperature of 33°C, all stages of O. (O.) yothersi died (McGregor, 1941). Oligonychus (O.) ilicis was able to complete development at 35°C. The developmental time (larva to adult) was shorter for O. (O.) ununguis (Garman, 1923) than for O. (O.) ilicis in this study; incubation times of O. (O.) ununguis and O. (O.) ilicis were similar. Developmental times for immature O. (O.) coffea were shorter than those of O. (O.) ilicis (Das and Das, 1967). Calsa and Sauer (1952) found the incubation period of O. (O.) ilicis eggs at 22.5°C to be 7.2 days. This was a shorter period than noted in the present study which lasted about 12 days at 21° and 9.4 days at 26.5°C. Calsa and Sauer (1952) also reported that the completion of the O. (O.) ilicis life cycle (egg to adult) averaged 7 days at 23°C. At 26.5°C in the present study, about 19 days were needed for life cycle completion.

In general, the range for developmental times decreased as temperature increased (Table 1). For eggs, larvae, protonymphs, and adults a drop in both the minimum and maximum developmental times was noted until temperatures of 32 or 35°C were reached, and then an increase was observed. The maximum time for egg development occurred at 15.5 and the minimum at 37.5°C. The maximum time for larval development occurred at 15.5 and the minimum at 29.5 and 35°C. The maximum developmental time for a protonymph was recorded at 15.5 and the same minimum developmental time

Table 1. Minimum and maximum developmental times in days for immature stages of the southern red mite, Oligonychus (Oligonychus) ilicis (McGregor), reared at 7 constant temperatures on Ilex crenata 'Hetzii' leaves in 1979.¹

Temperature (°C)	Stage				
	Egg	Larva	Protonymph	Deutonymph	Adult Longevity
15.5	16-24.5 (8.5)	6.5-15 (8.5)	6-11.5 (5.5)	6-9 (3)	7-23.5 (16.5)
21.0	10.5-15.5 (5)	3-9 (6)	2-7 (5)	2.5-9.5 (7)	6.5-41 (34.5)
26.5	6.5-11 (4.5)	2-5.5 (3.5)	1.5-6 (4.5)	2-4.5 (2.5)	3.5-12 (8.5)
29.5	6-8.5 (2.5)	1-4.5 (3.5)	1.5-4.5 (3)	2-5 (3)	0.5-18.5 (18)
32.0	3-7.5 (4.5)	1.5-2.5 (1)	1.5-7 (5.5)	1.5-3.5 (2)	1-6 (5)
35.0	4-7 (3)	1-3 (2)	1.5-3.5 (2)	1-5 (4)	0.5-7.5 (7)
37.0	1-8 (7)	2-2.5 (.5)	---	---	---

¹Numbers in parentheses are range values.

occurred at 26.5, 29.5, 32, and 35°C. For deutonymphs, the longest time required for development was observed at 21°C and the shortest time at 35°C. Greatest adult longevity occurred at 21 and the shortest at 29.5 and 35°C.

Males developed more rapidly than females at all temperatures except 26.5°C in 1978 when developmental times for males and females differed by less than a half-day (Table 2). No males reached adulthood at 15.5°C. Zaher and Shehata (1971) observed that O. (O.) mangiferus males emerged 12 to 36 hours before females. Malcolm (1955) found that, on the average, male Banks grass mites, O. (R.) pratensis, required a slightly shorter time to complete their life cycle than did females. Mean developmental times for both sexes of the southern red mite for eggs, larvae, protonymphs, and deutonymphs were shorter in 1978 at 21 and 26.5°C than in 1979. The mean for adult male longevity was greater than the mean for female longevity at 21 and 32°C. At all other temperatures, female longevity was greater.

Linear, quadratic, and cubic models were used to determine the shape of the developmental curves for life history data collected in 1979. The developmental curves for all stages were cubic. This differs from the findings of Tanigoshi and Logan (1979) who reported the developmental curves for eggs and immature life stages of Tetranychus (Armenychus) macdanieli McGregor to be quadratic in form "with the latter curves being asymmetrical about the minimum developmental point" (p. 166). Curves for the quiescent stages

Table 2. Mean days ($\pm$ SE) required for development of eggs, larvae, protonymphs, and deutonymphs, and longevity of males and females, Oligonychus (Oligonychus) ilicis (McGregor), reared at 5 constant temperatures on Ilex crenata "Hetzii" leaves.

Temperature (°C)	Year	Sex	No. Individuals Observed	Stage				
				Egg	Larva	Protonymph	Deutonymph	Adult
15.5	1979	M ¹ F	7	18.4 $\pm$ 0.2	9.4 $\pm$ 0.5	8.8 $\pm$ 0.6	7.4 $\pm$ 0.5	14.6 $\pm$ 2.8
21.0	1978 ²	M	18	9.4 $\pm$ 0.1	3.2 $\pm$ 0.1	3.1 $\pm$ 0.2	3.4 $\pm$ 0.2	8.1 $\pm$ 1.3
		F	32	9.1 $\pm$ 0.1	3.7 $\pm$ 0.2	3.3 $\pm$ 0.2	4.1 $\pm$ 0.3	8.0 $\pm$ 0.8
21.0	1979	M	14	12.4 $\pm$ 0.1	4.6 $\pm$ 0.4	3.7 $\pm$ 0.2	3.9 $\pm$ 0.3	16.4 $\pm$ 2.2
		F	17	11.5 $\pm$ 0.2	4.4 $\pm$ 0.2	3.9 $\pm$ 0.3	5.2 $\pm$ 0.5	15.0 $\pm$ 2.3
26.5	1978	M	21	6.3 $\pm$ 0.1	2.0 $\pm$ 0.5	2.1 $\pm$ 0.1	2.4 $\pm$ 0.2	5.1 $\pm$ 0.7
		F	13	5.4 $\pm$ 0.1	2.4 $\pm$ 0.1	2.3 $\pm$ 0.1	2.5 $\pm$ 0.2	8.7 $\pm$ 1.3
26.5	1979	M	5	9.5 $\pm$ 0.2	2.6 $\pm$ 0.4	3.5 $\pm$ 0.9	3.6 $\pm$ 0.6	7.6 $\pm$ 1.3
		F	2	11.5 $\pm$ 0.5	3 $\pm$ 0.0	4 $\pm$ 1.5	3 $\pm$ 0.0	9.5 $\pm$ 2.5
29.5	1979	M	3	6.2 $\pm$ 0.2	2.7 $\pm$ 0.3	2.0 $\pm$ 0.3	2.3 $\pm$ 0.3	2.3 $\pm$ 1.2
		F	9	6.0 $\pm$ 0.0	1.8 $\pm$ 0.2	2.9 $\pm$ 0.2	2.9 $\pm$ 0.3	9.9 $\pm$ 1.6
32.0	1979	M	1	5.5	1.5	1.5	1.5	5
		F	4	5.3 $\pm$ 0.3	2.0 $\pm$ 0.0	3.0 $\pm$ 0.3	2.3 $\pm$ 0.4	3.3 $\pm$ 1.1
35.0	1979	M	3	5.2 $\pm$ 0.2	2.2 $\pm$ 0.4	1.8 $\pm$ 0.2	1.7 $\pm$ 0.7	2.2 $\pm$ 1.0
		F	2	5.5 $\pm$ 0.5	1.3 $\pm$ 0.3	2.0 $\pm$ 0.5	3.3 $\pm$ 1.8	5.5 $\pm$ 2.0

¹No males reached adulthood at 15.5°C.

²Photoperiod was 10:14 L:D. Photoperiods for all other temperatures were 12:12 L:D.

and preoviposition period of T. (A.) macdanieli were also cubic.

A general decreasing pattern existed in the length of preoviposition, oviposition, and postoviposition as the temperature increased (Table 3). The maximum preoviposition period occurred at 21° (1978) and the minimum at 32°C. The maximum oviposition period in 1979 occurred at 26.5 and the minimum at 32 and 35°C. Postoviposition maximum and minimum values were found at 15.5 and 26.5°C (1979), respectively. At all temperatures females producing eggs had a greater longevity than females not producing eggs.

The maximum rate of oviposition was affected by temperature (Fig. 2). At 15.5°C the highest ovipositional rate occurred on the seventh day. At 21°C peak oviposition was reached at 9 days in 1978 and 16 days in 1979. At 26.5°C, peak oviposition occurred on day 6 in 1978 and on day 9 in 1979. At 29.5, 32, and 35°C the peaks occurred at 6, 3, and 4 and 5 days, respectively. Egg production appears to be erratic particularly at lower temperatures (15.5° and 21°C). Generally, the oviposition period decreased in length as the temperature increased, with more eggs produced per day. Tan and Ward (1977) observed maximum egg production of O. (R.) pratensis on day 6, with an average of 12 eggs per female.

Egg production by O. (O.) ilicis showed an increase from 15.5 to 21° followed by a slight decrease at 26.5°C. A reduction in the length of the ovipositional period

Table 3. Mean days ($\pm$ SE) required for preoviposition, oviposition and postoviposition periods and longevity of female southern red mites, *Oligonychus* (*Oligonychus*) *ilicis* (McGregor), producing eggs and females not producing eggs at 5 constant temperatures.

Temperature (°C)	Year	Preoviposition	Oviposition	Postoviposition	Female Longevity	
					Eggs Produced	Eggs not Produced
15.5	1979	2.9 $\pm$ 0.7 (5) ²	5.4 $\pm$ 2.0 (5)	9.1 $\pm$ 1.1 (5)	17.4 $\pm$ 3.0 (5)	7.5 $\pm$ 0.5 (2)
21.0 ¹	1978	3.2 $\pm$ 0.6 (15)	3.5 $\pm$ 1.1 (15)	4.1 $\pm$ 0.5 (15)	10.8 $\pm$ 1.3 (15)	5.4 $\pm$ 0.7 (17)
21.0	1979	2.8 $\pm$ 0.3 (16)	5.5 $\pm$ 1.6 (16)	7.2 $\pm$ 2.0 (16)	15.4 $\pm$ 2.4 (16)	8.5 (1)
26.5	1978	1.0 $\pm$ 0.2 (11)	6.9 $\pm$ 1.2 (11)	1.6 $\pm$ 0.3 (11)	9.8 $\pm$ 1.2	2.8 $\pm$ 2.3 (2)
26.5	1979	1.5 (1)	10 (1)	1 (1)	12 (1)	7 (1)
29.5	1979	2.5 $\pm$ 0.3 (8)	4.0 $\pm$ 1.2 (8)	3.8 $\pm$ 0.9 (8)	10.3 $\pm$ 1.8 (8)	7 (1)
32.0	1979	0.5 $\pm$ 0.7 (2)	1.8 $\pm$ 1.8 (2)	1 $\pm$ 0.0 (2)	4.3 $\pm$ 1.8 (2)	2.3 $\pm$ 1.3 (2)
35.0	1979	1.8 $\pm$ 1.8 (2)	1.8 $\pm$ 0.8 (2)	2.0 $\pm$ 1.0 (2)	5.5 $\pm$ 2.0 (2)	---

¹Photoperiod was 10:14 (L:D). Photoperiods for all other temperatures were 12:12 (L:D).

²Numbers in parentheses represent the number of individuals observed.

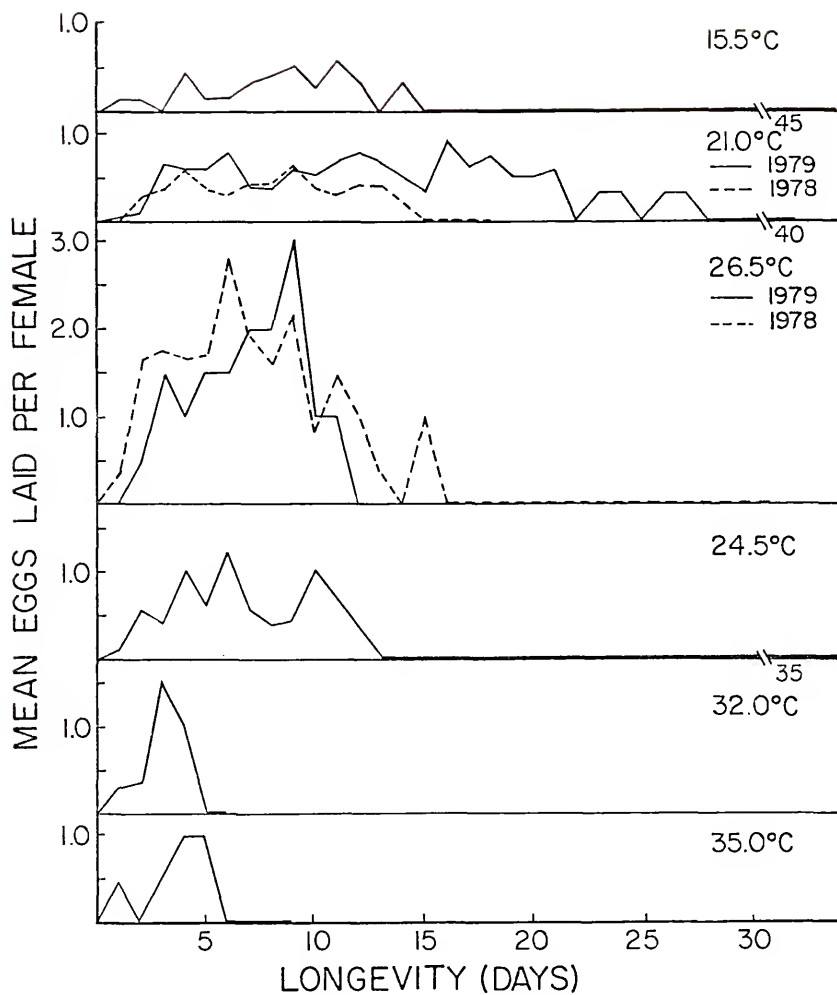


Fig. 2. Mean eggs laid per female *Oligonychus* (*Oligonychus*) *ilicis* (McGregor) per day at 6 constant temperatures on *Ilex crenata* 'Hetzii' leaves.

occurred at temperatures above 26.5°C. At 15.5°C the number of eggs produced by females laying eggs ranged from 1 to 7. At 21°C in 1979 the range was from 1 to 33; in 1978 the range for eggs deposited was 1 to 26. For 26.5°C the range was 1 to 28 in 1978. In 1979, at 26.5°C only one female produced eggs, and she laid 22 in an oviposition period of 10 days. At 29.5°C, the range in eggs laid was 1 to 18. For 32 and 35°C the ranges were 1 to 5 and 2 to 3 eggs, respectively.

The number of eggs produced by different species of the genus Oligonychus was quite variable. Das (1959) found that the maximum number of eggs laid per female O. (O.) coffeae varied from 50 in July to 137 in May. Hu and Wang (1965) recorded the maximum number of eggs of O. (O.) coffeae as 38 in January and 127 in December. The number of eggs produced per female O. (O.) coffeae decreased as temperature increased (Das and Das, 1967). The number of eggs laid per female ranged from 43 to 159, 53 to 129, 47 to 104, 39 to 93, and 2 to 21 at 20, 25, 27, 30, and 32°C, respectively. The number of eggs deposited per female O. (O.) mangiferus changed according to seasons, averaging 24 in the spring, 30 in summer, 34 in autumn, and 20 in winter (Zaher and Shehata, 1971). Akita (1971) found the average fecundity of O. (O.) ununguis higher in the summer than in the spring; the maximum number of eggs produced per female was at 25°C, with an average of 43 eggs. The average number of eggs laid per female O. (H.) platani on Pyracantha sp. was

9 at 29°, 35 at 24°, and 17 at 15°C (Butler and Abid, 1965). Gupta et al. (1975) recorded the range of eggs laid per female sugarcane red mite, O. (R.) indicus, to be from 193 on sorghum at 33° to 4 on maize at 35 and 28°C. The total number of eggs laid per female O. (R.) oryzae ranged from 7 to 21 (Misra and Israel, 1968). Malcolm (1955) recorded a maximum of 147 eggs for a female Banks grass mite, O. (R.) pratensis. The average number of eggs varied with the generations, but the mean number of eggs laid per female over the entire season was 61. Elmer (1965) observed a much lower egg production of O. (R.) pratensis at room temperature in the laboratory on dates; eggs deposited varied between 10 and 21 eggs per female. Tan and Ward (1977) recorded higher ranges for O. (R.) pratensis reared on sorghum. Total eggs per female ranged from 75 to 150, 90 to 160, and 98 to 151 at temperatures ranging from 27 to 41, 24 to 35, and 27 to 38°C, respectively. The findings of Calsa and Sauer (1952) agreed with the present study. Oligonychus (O.) ilicis females reared on coffee usually deposited 10 to 15 eggs with a maximum of 24 eggs recorded for one female.

Mortality curves were plotted for males (Fig. 3) and females (Fig. 4), and as temperature increased, the curves dropped more abruptly. For males the curves for 29.5 and 35° (not shown in Fig. 3) exhibited the same trend as for 32°C. The slopes of the curves for female mortality were not as steep as those for males. The data for female mortality at

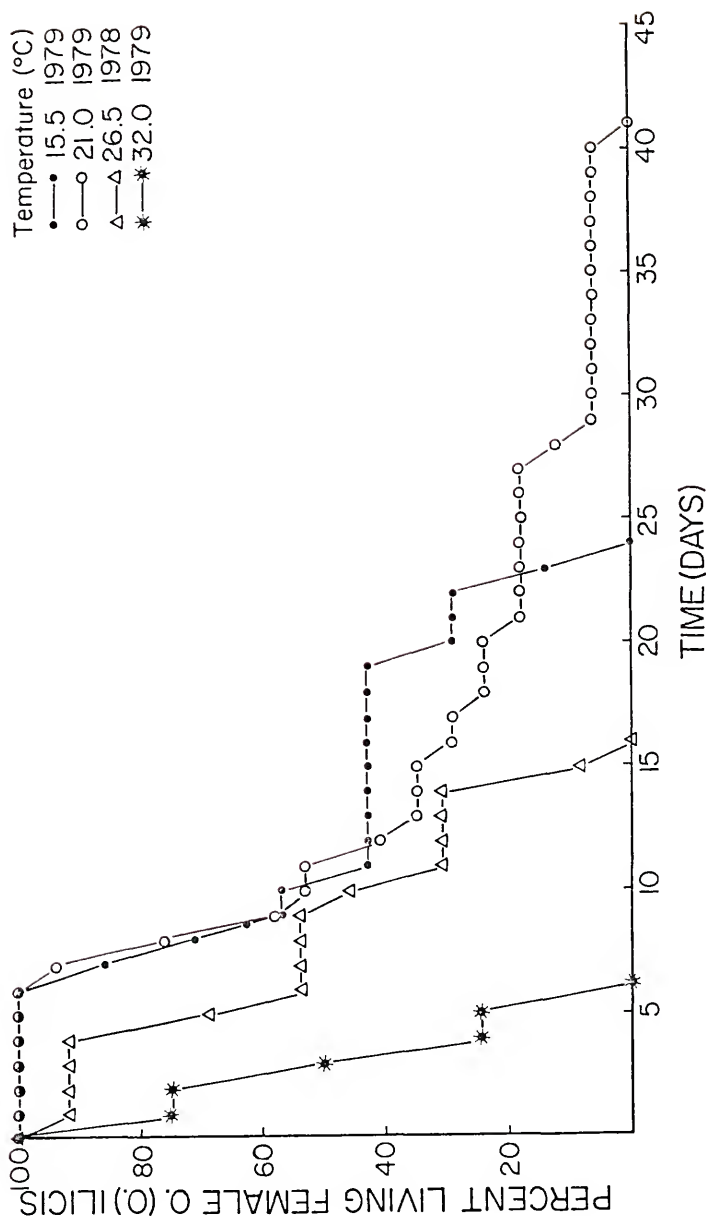


Fig. 3. Mortality curves for adult female *Oligonychus ilicis* (McGregor) reared at 4 constant temperatures on holly leaves, *Ilex crenata* 'Hetzii'.

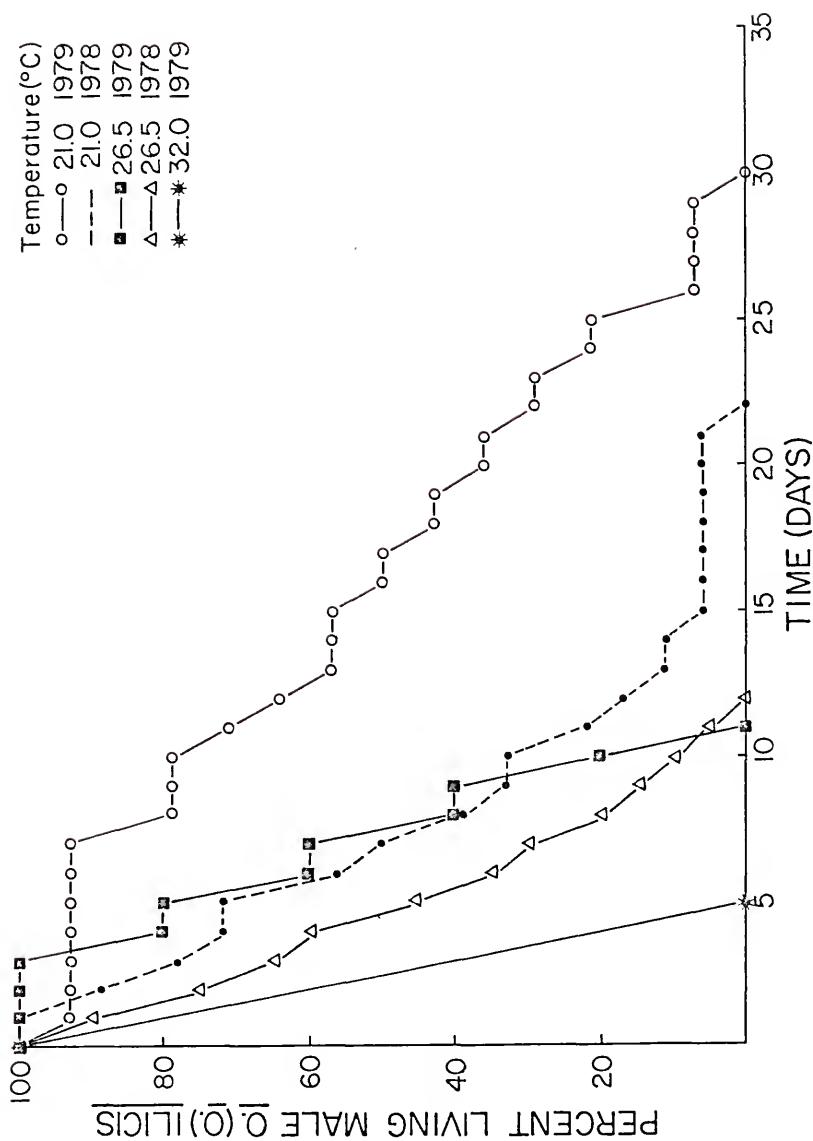


Fig. 4. Mortality curves for adult male *Oligonychus ilicis* (McGregor) reared at 3 constant temperatures on holly leaves, *Ilex crenata* 'Hetzii.'

21° (1978), 26.5° (1979), 29.5° and 35°C (not shown in Fig. 4) exhibited the same general trend as in the 26.5°C (1978) curve.

Stage-specific life tables were constructed for mites reared at each temperature in 1979 (Tables 4-10). The survival rate was greatest for eggs, with a greater percentage of eggs developing into larvae at 21°C than at any other temperature (Table 5). The highest survival rates of larvae, protonymphs, and deutonymphs also occurred at 21°C. The second highest survival rates of all stages occurred at 29.5°C (Table 7). The lowest survival rate for eggs was recorded for 35°C (Table 9). The lowest survival rates of larvae and protonymphs occurred at 37.5°C (Table 10). Lowest deutonymphal survival was at 35°C. The highest mortality occurred in the larval stage. If mites survived until the larval stage, their chances of reaching adulthood were ca 75%. Next highest mortality occurred in the protonymphal stage for all temperatures except 21°C where a greater number of mites died as deutonymphs than as protonymphs. The percent mortality of O. (O.) ilicis was greater in all of the immature stages when compared with the Banks grass mite O. (R.) pratensis (Tan and Ward, 1977).

Net reproductive rate, mean generation time, and intrinsic rate of natural increase were positively and negatively correlated with temperature (Table 11). The highest net reproductive rates occurred at 26.5°C. The net reproductive rates showed an upward trend from 15.5° to 26.5° and then dropped at higher temperatures. The mean generation

Table 4. Stage-specific life table for one generation of southern red mite, *Oligonychus* (*Oligonychus*) *ilicis* (McGregor), reared at 15.5°C on excised holly leaves, *Ilex crenata* 'Hetzii'.

Stage	No. Alive	No. Dying	Apparent Mortality ¹	Real Mortality ²	Survival Rate ³
Egg	79	7	8.9	8.9	91.1
Larva	72	51	70.8	64.6	26.6
Protonymph	21	11	52.4	13.9	12.7
Deutonymph	10	3	30.0	3.8	8.9
Adult	7	7	100.0	8.9	0.0

¹Percent of those individuals reaching the stage that died during the stage.

²Percent of the initial cohort dying during the stage.

³Percent of the initial cohort remaining alive at the end of the stage.

Table 5. Stage-specific life table for one generation of the southern red mite, Oligonychus (Oligonychus) ilicis (McGregor), reared at 21°C on excised holly leaves, Ilex crenata 'Hetzii'.

Stage	No. Alive	No. Dying	Apparent, Mortality ¹	Real Mortality ²	Survival Rate ³
Egg	117	4	3.4	3.4	96.6
Larva	113	60	53.1	51.3	45.3
Protonymph	53	10	18.9	8.5	36.8
Deutonymph	43	12	27.9	10.2	26.5
Adult	31	31	100.0	26.5	0.0

¹Percent of those individuals reaching the stage that died during the stage.

²Percent of the initial cohort dying during the stage.

³Percent of the initial cohort remaining alive at the end of the stage.

Table 6. Stage-specific life tables for one generation of the southern red mite, Oligonychus (Oligonychus) ilicis (McGregor), reared at 26.5°C on excised holly leaves, Ilex crenata 'Hetzii'.

Stage	No. Alive	No. Dying	Apparent Mortality ¹	Real Mortality ²	Survival Rate ³
Egg	124	9	7.3	7.3	92.7
Larva	115	76	66.1	61.3	31.5
Protonymph	39	23	59.0	18.5	12.9
Deutonymph	16	9	56.3	7.3	5.6
Adult	7	7	100.0	5.6	0.0

¹Percent of those individuals reaching the stage that died during the stage.

²Percent of the initial cohort dying during the stage.

³Percent of the initial cohort remaining alive at the end of the stage.

Table 7. Stage-specific life table for one generation of the southern red mite, Oligonychus (Oligonychus) ilicis (McGregor), reared at 29.5°C on excised holly leaves, Ilex crenata 'Hetzii'.

Stage	No. Alive	No. Dying	Apparent Mortality ¹	Real Mortality ²	Survival Rate ³
Egg	101	6	5.9	5.9	94.1
Larva	95	60	63.2	59.4	34.7
Protonymph	35	19	54.3	18.8	15.8
Deutonymph	16	4	25.0	4.0	11.9
Adult	12	12	100.0	11.9	0.0

¹Percent of those individuals reaching the stage that died during the stage.

²Percent of the initial cohort dying during the stage.

³Percent of the initial cohort remaining alive at the end of the stage.

Table 8. Stage-specific life table for one generation of the southern red mite, Oligonychus (Oligonychus) ilicis (McGregor), reared at 32°C on excised holly leaves, Ilex crenata 'Hetzii'.

Stage	No. Alive	No. Dying	Apparent Mortality ¹	Real Mortality ¹	Survival Rate ³
Egg	109	7	6.4	6.4	93.6
Larva	102	77	75.4	70.6	22.9
Protonymph	25	17	68.0	15.6	7.3
Deutonymph	8	3	37.5	2.8	4.6
Adult	5	5	100.0	4.6	0.0

¹Percent of those individuals reaching the stage that died during the stage.

²Percent of the initial cohort dying during the stage.

³Percent of the initial cohort remaining alive at the end of the stage.

Table 9. Stage-specific life tables for one generation of the southern red mite, Oligonychus (Oligonychus) ilicis (McGregor), reared at 35°C on excised holly leaves, Ilex crenata 'Hetzii'.

Stage	No. Alive	No. Dying	Apparent ¹ Mortality ¹	Real Mortality ¹	Survival Rate ³
Egg	79	16	20.3	20.3	79.7
Larva	63	39	61.9	49.4	30.4
Protonymph	24	14	58.3	17.7	12.7
Deutonymph	10	5	50.0	6.3	6.3
Adult	5	5	100.0	6.3	0.0

¹Percent of those individuals reaching the stage that died during the stage.

²Percent of the initial cohort dying during the stage.

³Percent of the initial cohort remaining alive at the end of the stage.

Table 10. Stage-specific life table for one generation of the southern red mite, Oligonychus (Oligonychus) ilicis (McGregor), reared at 37.5°C on excised holly leaves, Ilex crenata 'Hetzii'.

Stage	No. Alive	No. Dying	Apparent Mortality ¹	Real Mortality ¹	Survival Rate ³
Egg	42	8	19.0	19.0	81.0
Larva	34	31	91.2	73.8	7.1
Protonymph	3	3	100.0	7.1	0.0
Deutonymph	--	--	--	--	--
Adult	--	--	--	--	--

¹Percent of those individuals reaching the stage that died during the stage.

²Percent of the initial cohort dying during the stage.

³Percent of the initial cohort remaining alive at the end of the stage.

Table 11. Net reproductive rate, mean generation time, and intrinsic rate of natural increase for Oligonychus (Oligonychus) ilicis (McGregor) reared on Ilex crenata 'Hetzii' at 6 constant temperatures.

Temperature (°C)	Year	Net Reproductive Rate	Mean Generation Time	Intrinsic Rate of Natural Increase
15.5	1979	1.4914	7.1127	.0562
21.0	1978	1.4693	5.5134	.0698
21.0	1979	3.7811	7.3119	.1819
26.5	1978	7.0961	4.1745	.4694
26.5	1979	6.3800	5.2260	.3546
29.5	1979	2.9466	5.0100	.2157
32.0 ¹	1979	--	--	--
35.0	1979	1.4500	2.5695	.1446

¹Insufficient data for calculations.

time was shortest at 35°C; data for 32°C were insufficient for accurate calculation of this value. The longest mean generation times were calculated for 15.5 and 21°C. In general, mean generation times were greater at lower temperatures. Intrinsic rate of natural increase was greatest at 26.5°C and lowest at 15.5°C. Intrinsic rates of natural increase showed an upward trend as temperatures increased to 26.5°C and then dropped at temperatures above 26.5°C.

Banerjee (1975) found greater net reproductive rates for O. (O.) coffeae on two tea varieties than were exhibited by O. (O.) ilicis at any temperature. The mean generation times for O. (O.) ilicis at all temperatures except 32 and 35°C were longer than those of O. (O.) coffeae. Intrinsic rates of increase for O. (O.) coffeae on China and Assam tea at 23°C and 85% relative humidity were 0.81 and 0.72, respectively. These values were higher than those found for O. (O.) ilicis at any temperature. Laing (1969) found that the population of Tetranychus (Tetranychus) urticae Koch multiplied 30.93 times under a diurnal temperature cycle of 15 to 28°C. The mean generation time was 24 days. The intrinsic rate of increase for T. (T.) urticae was 0.143. Under this fluctuating temperature regime, the net reproductive rate was larger and the mean generation time was longer for T. (T.) urticae than those for O. (O.) ilicis reared at constant temperatures. The value for the

intrinsic rate of increase was less for T. (T.) urticae than that found for O. (O.) ilicis at 5 temperatures.

The number of degree days required for the development of each immature stage at 6 different temperatures indicated that the egg stage required the greatest amount of heat (Table 12). Values for temperatures above 15.5° were all greater than values for stages at 15.5°C. A greater percentage of degree days was required for egg development (Fig. 5). A general downward trend in percentages can be observed for larvae as the temperature increased, but this was not seen for protonymphs and deutonymphs. Tanigoshi and Logan (1979) stated that the degree days concept was not valid over the entire developmental range for spider mite populations because of the concept's inherent linearity between rate of development and temperature.

Conclusion

Southern red mites completed development through all stages under constant temperatures ranging from 15.5 to 35°C. In general, developmental times of all stages and adult longevity decreased as temperatures increased. Males developed more rapidly than females at all temperatures except 26.5°C. The developmental curves for all stages were cubic. The maximum rate of oviposition was affected by temperature, and the length of preoviposition, oviposition, and postoviposition generally decreased as the temperature increased. Mortality curves for males and females

Table 12. Degree days required for development of eggs, larvae, protonymphs, and deutonymphs of Oligonychus (Oligonychus) ilicis (McGregor) at 6 constant temperatures.

Stage	Temperature					
	15.5	21.0	26.5	29.5	32.0	35°
Egg	18.4	77.7	112.8	93	92.8	115.8
Larva	9.4	28.9	40.2	33.8	36.8	29.7
Protonymph	8.8	24.1	37.8	42.8	57.8	45.1
Deutonymph	7.5	29.9	40.8	41.3	36.8	47.2

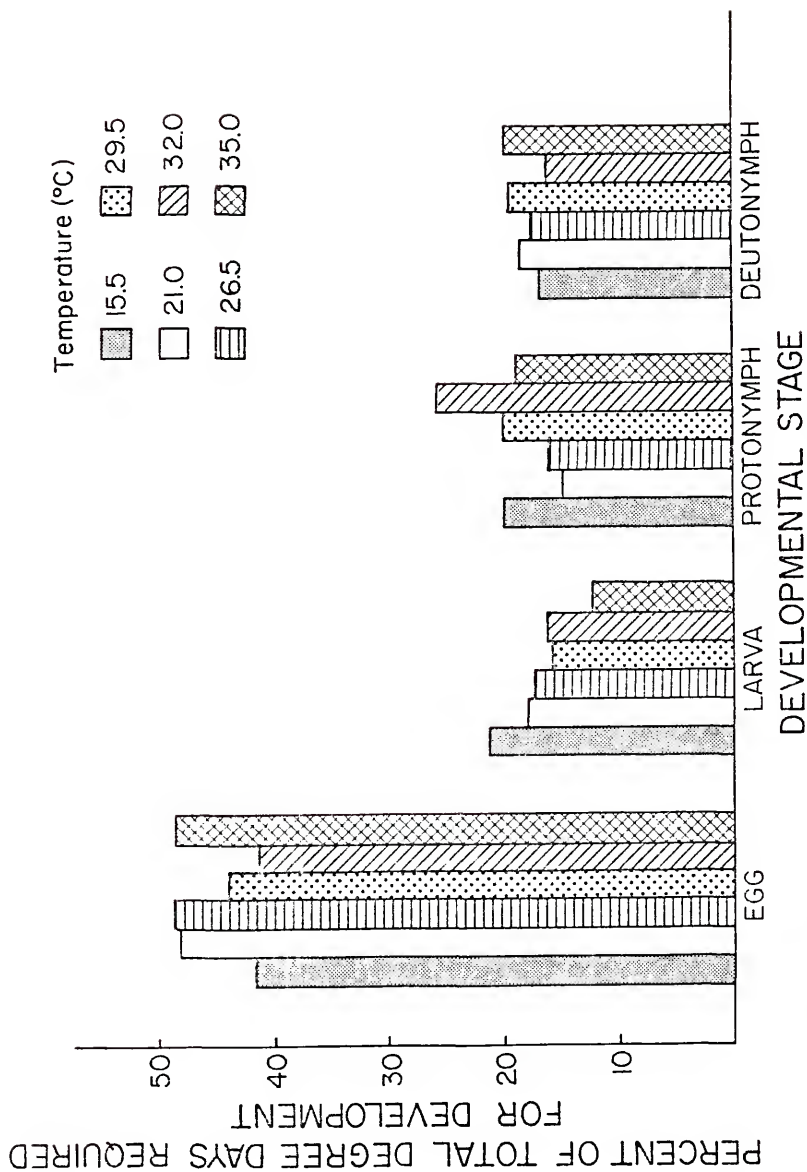


Fig. 5. Percentages of degree days required for development of eggs, larvae, protonymphs, and deutonymphs of *Oligonychus (oligonychus) ilicis* (McGregor) reared at 6 constant temperatures on *Ilex crenata* 'Hetzii'.

dropped more abruptly as temperature increased. The survival rate of O. (O.) ilicis was greatest for eggs, and the highest mortality occurred in the larval stage. The net reproductive rate was highest (7.0961) at 26.5°C. The mean generation time was shortest (2.5695) at 35° and longest (7.3119) at 21°C. The intrinsic rate of natural increase was greatest (0.4694) at 26.5°C. The number of degree days required for development of each immature stage at 6 different temperatures indicated that the egg stage required the greatest amount of heat.

SPATIAL DISTRIBUTION OF Oligonychus (Oligonychus) ilicis
(McGregor) ON FIELD GROWN Ilex crenata 'Hetzii'

Introduction

Information concerning the spatial distribution of an insect or mite on its host plant is essential in pest management programs to estimate population densities accurately. In many instances, pests exhibit a preference for a particular location on a host plant (Broadbent, 1948; Morris, 1955; Hudson and LeRoux, 1961; MacLellan, 1962; Paradis and LeRoux, 1962). A knowledge of this distribution can greatly increase efficiency of a pest management program by reducing both sample variability and size (Southwood, 1978).

The purpose of the present study was to determine the spatial distribution of Oligonychus (Oligonychus) ilicis (McGregor), the southern red mite, on field grown Ilex crenata 'Hetzii' and thereby define the optimum sampling location.

Literature Review

Many tetranychid species have a preferred location on a host plant but will move to other plant parts when populations become high. A mite species may also have a different habitat preference on different host plants. The twospotted

spider mite, Tetranychus (Tetranychus) urticae Koch, preferred the upper leaf surface of some plants and the under surface of others while infesting both surfaces of many of its hosts (Jeppson et al., 1975). Species of Oligonychus have exhibited habitat preferences. Oligonychus (O.) bicolor (Banks), the oak mite, has been observed to feed on the upper leaf surface and occasionally on the bark of young twigs of oaks and other ornamental trees (Jeppson et al., 1975). The tea red spider mite, O. (O.) coffaeae (Nietner), was found in colonies usually on the upper surface of older leaves but inhabited both surfaces during severe infestations or drought. During drought, O. (O.) coffaeae moved to new growth which had become less turgid and, thus, more susceptible to attack (Das, 1959). Infestations of O. (O.) mangiferus (Rahman and Sapra) occurred on the upper leaf surfaces of its hosts (Mohamed, 1963; Moutia, 1958; Zaher and Shehata, 1971). Adult females of O. (O.) newcomeri (McGregor) were found primarily on upper leaf surfaces of serviceberry, Amelanchier sp., and hawthorn, Crataegus sp., while males and quiescent forms were commonly seen on lower surfaces (Jeppson et al., 1975). The avocado brown mite, O. (O.) punicae (Hirst), first began feeding on the upper surface of avocado leaves along the midrib and then along the smaller veins, and eventually in heavy infestations spread over the entire upper leaf surface (Ebeling, 1959). Pierce (1953) reported O. (O.) viridis (Banks) on both surfaces of pecan leaflets, but feeding and reproduction

occurred principally on the upper surface. The avocado red mite, O. (O.) yothersi (McGregor), also fed on the upper leaf surface (McKenzie, 1935). Butler and Abid (1965) observed O. (Homonychus) platani (McGregor) producing bronzing and unsightly webbing on both leaf surfaces of Pyracantha coccinea (Roem.). Eggs were initially deposited on the upper surface along the midrib, and eggs laid after the population began to grow were scattered over the entire upper surface. Oligonychus (H.) peruvianus (McGregor) and O. (Metatetranychus) aceris (Shimer) occurred predominantly on the underside of leaves (Baker and Pritchard, 1953; Reeves, 1963).

In addition to leaf surface, the position of a leaf or shoot and whether it is in the upper, middle, or lower part of a tree or plant influences the preference of insects or mites for it (Southwood, 1978). Koehler and Frankie (1968) reported the density of active stages of the mite, O. (Wainsteiniella) subnudus (McGregor), on Monterey pine to advance on the growth as the growing season progressed. Citrus rust mites, Phyllocoptruta oleivora (Ashmead), were recorded in greatest numbers from the lower portion of citrus trees (Allen and McCoy, 1979). Smith (1939) observed the foliage in the lower portions of walnut trees to be more heavily infested with O. (O.) ilicis than higher in the tree.

Studies by other investigators have detected variations in mite and insect numbers in relation to direction.

More winter eggs of red spider mites were observed by Friedrich (1951) on the sides of cherry and almond trees that were protected from the general wind direction. Malcolm (1955) observed that occasionally Banks grass mites, O. (Reckiella) pratensis (Banks), did most of their winter feeding on the southern exposure of grass rows, apparently because this side was warmer. Kremer (1956) found the clover mite, Bryobia praetiosa Koch, to lay more winter eggs on the east and south sides of fruit trees in Germany. Dean (1959) sampled three species of mites from the terminal-flush grapefruit leaves in various quadrants of trees. Brevipalpus spp. were more numerous in the west quadrants. Citrus rust mites, P. oleivora, were most abundant on the east and north sides of the tree during eight months of the year. Greatest number of Eutetranychus banksi (McGregor) was collected from the south quadrants except for two months following the peak populations. Rust mites on citrus tended to favor semishade and avoid bright sunlight (Yothers and Mason, 1930; Albrigo and McCoy, 1974; van Brussel, 1975). Semishaded areas had higher mite densities than those of shaded groves and the shaded side of fruit (Yothers and Mason, 1930; Muma, 1970; McCoy and Albrigo, 1975). Avoidance of solar exposure was set forth by Allen and McCoy (1979) as the explanation for distribution of the citrus rust mite on individual fruit and in the entire citrus tree. More rust mites were found in the lower north quadrant where the most favorable temperatures

occurred. High mite densities were also observed in the favorable lower south quadrant, and lowest mite numbers were recorded from the south top quadrant where temperatures were often lethal.

Materials and Methods

The spatial distribution of O. (O.) ilicis on I. crenata was studied in March 1977. Samples from infested, commercially grown holly were taken at Blair Nursery near Macclenny, Florida.

The experimental plot (approximately 0.1 hectare) contained 20 north-south rows of untreated, one meter high plants. To the east, adjacent to the experimental plot, were 1.5 hectares of holly plants which were treated periodically with a dicofol-parathion mixture. Samples were taken from the center of the experimental plot to avoid the effects of pesticide drift from the treated area. Five contiguous plants were sampled in each of two rows, and 24 samples were collected from each plant. Each sample consisted of 10 leaves, and sampling sites were selected from lower, middle, and upper heights and from outer and inner zones of the plant. Samples from these 3 heights and 2 zones were further divided to represent the north, south, east, and west quadrants of the holly plants. All plant material was refrigerated until examined to prevent mite movement.

Since the leaves of I. crenata were somewhat cup-shaped and small, and ranged in size from approximately 2.5-3.5 cm², and since both counts of eggs and mites were desired, visual examination of plant material under a dissecting microscope was chosen as the most desirable sampling technique (Jeppson et al., 1975; Krantz, 1978).

Analysis of variance and Duncan's multiple range test were used to determine whether there were significant differences in the distribution patterns of eggs and mites in relation to heights, zones, and quadrants.

Results and Discussion

Mites and eggs were found primarily on the lower surface of holly leaves. Under crowded conditions mites and eggs were found on both leaf surfaces, with the majority on the underside. Denmark (1968) made these same observations, but this conflicted with the reports of Smith (1939) and Jeppson et al. (1975) which stated that O. (O.) ilicis lived almost exclusively on the upper surface of leaves of whatever plant it infested. Calsa and Sauer (1952) indicated the preference of O. (O.) ilicis for the upper surface of coffee leaves.

Since there is variability in preference for living and feeding sites among the Oligonychus species, conditions of the leaf surfaces such as hirsuteness or presence of plant exudates along with temperature and light requirements of the mites may influence mites to seek certain locations on

a given host. The upper leaf surface of I. crenata is waxy and smooth which may in some way discourage feeding and oviposition on that surface. Inhabiting the leaf undersurface affords protection from rain.

In addition to leaf surface, height of a living site may influence distribution of eggs and mites. Eggs were distributed evenly over the three heights (Fig. 6), there being no significant difference (Table 13). The distribution of mites was affected by height (Fig. 6). On I. crenata 26, 30, and 44% of the mites were located in the lower, middle, and upper parts of the plant, respectively. The mean number of mites in the upper portion of the plant was significantly greater than the means for the lower and middle strata (Table 13). When the combined means for eggs and mites were analyzed, no differences were found among the three heights.

The significantly greater number of mites in the upper portions of holly plants may be attributed to the general tendency of tetranychid mites to exhibit negatively geotropic movements. Whether this greater accumulation of mites in the upper part of the host was for dispersal purposes is uncertain. Masses of mites or webbing have not been observed at the tops of holly plants as are evident with members of the genus Tetranychus under crowded conditions and diminished food supply. Other members of the genus Oligonychus also produce webbing with crowded conditions. Calsa and Sauer (1952) reported that O. (O.) ilicis

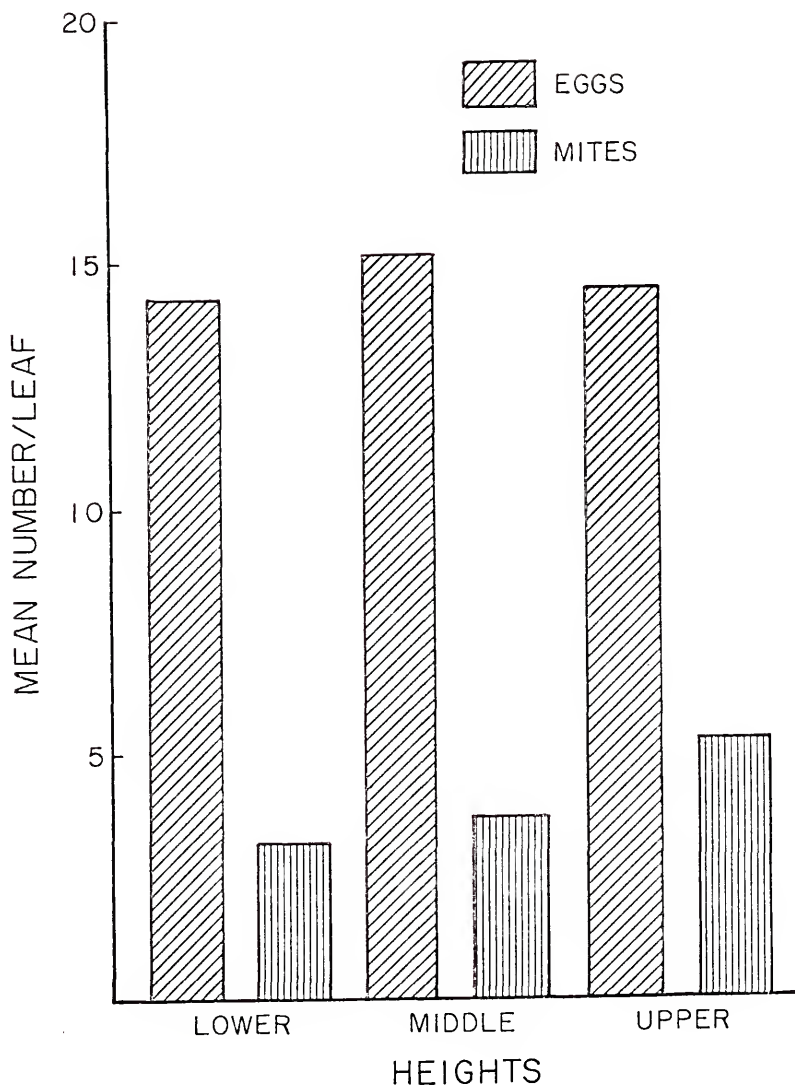


Fig. 6. Mean number of eggs and mites, *Oligonychus* (*Oligonychus*) *ilicis* (McGregor), per leaf from 3 different heights of *Ilex crenata* 'Hetzii.'

Table 13. Mean number of eggs and mites, *Oligonychus* (*Oligonychus*) *ilicis* (McGregor), per leaf from 2 zones, 3 heights, and 4 quadrants of *Ilex crenata* 'Hetzli.'

	Eggs $\pm$ SE ¹	Mites $\pm$ SE	Eggs and Mites Combined
Heights			
Lower	14.22 $\pm$ 1.28 a	3.14 $\pm$ 0.31 b	8.68 a
Middle	15.13 $\pm$ 1.51 a	3.65 $\pm$ 0.38 b	9.39 a
Upper	14.41 $\pm$ 1.16 a	5.31 $\pm$ 0.44 a	9.86 a
Zones			
Inner	17.75 $\pm$ 1.06 a	4.69 $\pm$ 0.34 a	11.22 a
Outer	11.42 $\pm$ 1.03 b	3.38 $\pm$ 0.28 b	7.40 b
Quadrants			
North	16.90 $\pm$ 1.46 ab	4.98 $\pm$ 9.48 a	10.94 a
East	12.09 $\pm$ 1.57 bc	3.38 $\pm$ 0.47 a	7.73 b
South	18.07 $\pm$ 1.59 a	4.45 $\pm$ 0.40 a	11.26 a
West	11.29 $\pm$ 1.31 c	3.33 $\pm$ 0.43 a	7.31 b

¹Means within heights, zones, and quadrants followed by the same letter are not significantly different at the 1% level by Duncan's multiple range test.

produced webbing on coffee leaves and utilized the webbing for movement on the leaf and also dropped on webbing to move from leaf to leaf and plant to plant. No webbing was noticed on I. crenata in this study. Thewke and Enns (1969) observed a small amount of webbing by O. (O.) ilicis on the leaves and stems of Japanese holly, I. crenata, but the cultivar was not given.

Egg and mite distribution in the inner and outer zones of the plants was also examined (Fig. 7). The inner zone contained 61% of the eggs, and the outer zone had 39%. The mean number of eggs for the inner zone differed significantly from the mean for the outer zone (Table 13). A similar pattern existed for mites. Fifty-eight percent of the mites were in the inner zone and 42% in the outer. The mean for the inner zone was significantly greater than the mean for the outer zone. A significant difference between the inner and outer zones also was found when the means for mites and eggs combined were analyzed.

The concentration of mites in the inner zone of the plants is not clearly understood. Ilex crenata plants are usually densely foliated; possibly the inner location provided protection from desiccating winds or from predators which might be more likely to contact the outer portion of the plant first. Predators observed included thrips, green lace wing larvae, cecidomyid larvae, coccinellid larvae and adults, and predaceous phytoseiid.

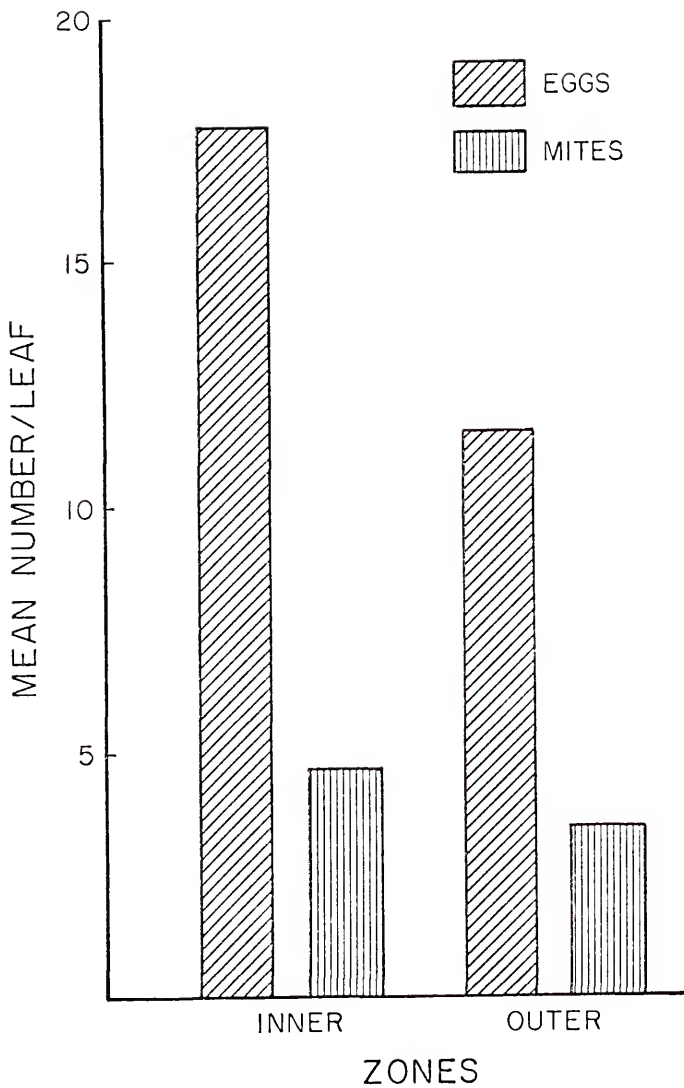


Fig. 7. Mean number of eggs and mites, Oligonychus (Oligonychus) ilicis (McGregor), per leaf from the inner and outer zones of Ilex crenata 'Hetzii.'

Additionally, the distribution of eggs and mites between the four quadrants was investigated (Fig. 8). More eggs and mites were located in the north and south quadrants than in the east and west quadrants. A significant difference for eggs was noted between the south quadrant and both the east and west quadrants. The mean for the north quadrant differed significantly from the west quadrant but not the east or south (Table 13). At the 5% level the number of eggs was significantly different between the east and north quadrants. Thirty-one percent of the eggs were found in the south, 29% in the north, 21% in the east, and 19% in the west quadrant. No statistical difference was found in the numbers of mites in the north, south, east, or west quadrants of the plants. At the 5% level the number of mites was significantly different between the north and the east and west quadrants. Thirty-one percent of the mites were in the north quadrant, 27% in the south, and 21% in both the east and west quadrants. When the combination of eggs and mites was examined, the north and south quadrants differed significantly (1% level) from the east and west quadrants.

Eggs and mites in the north and south quadrants were afforded some protection from wind because branches of adjacent plants overlapped. East and west quadrants were more exposed.

Citrus rust mites were also found in greatest numbers in the north and south quadrants of their host (Allen and

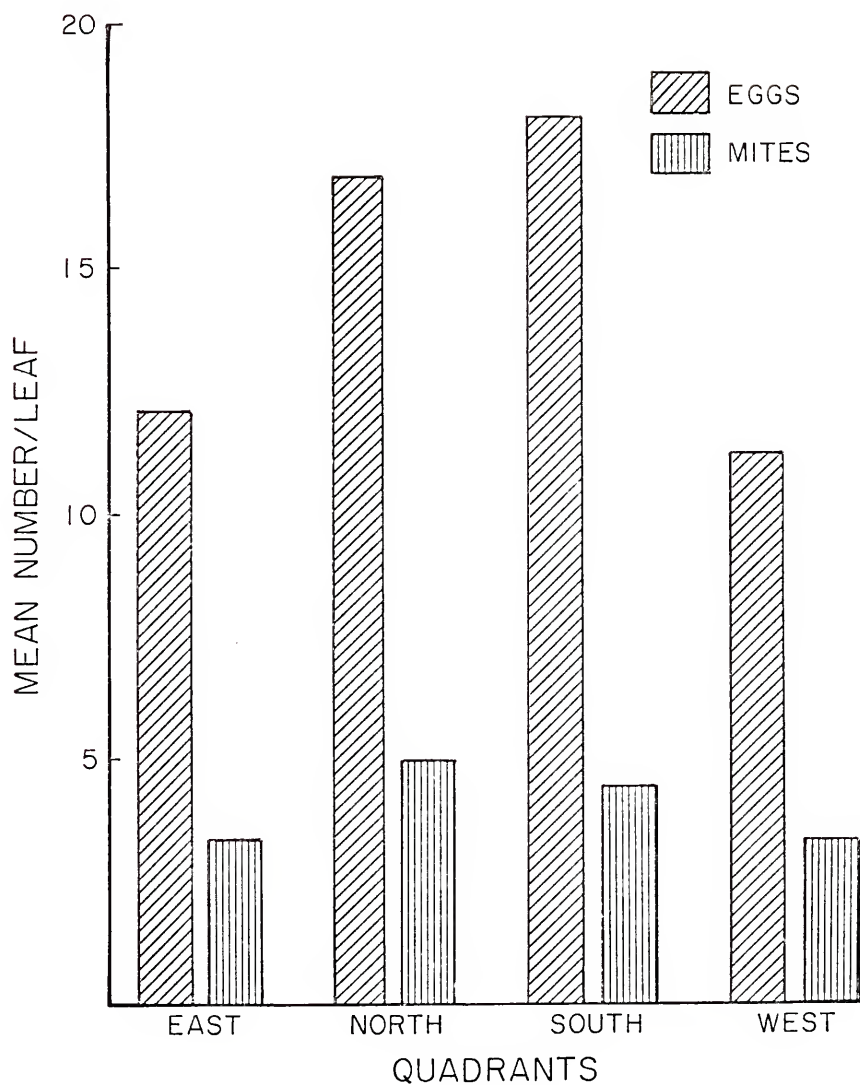


Fig. 8. Mean number of eggs and mites, *Oligonychus* (*Oligonychus*) *ilicis* (McGregor), per leaf from 4 quadrants of *Ilex crenata* 'Hetzii.'

McCoy, 1979), but unlike southern red mites, the rust mites were found in the lower parts of trees. No interaction for zones and heights was found for O. (O.) ilicis eggs. All heights in the inner zone contained more eggs than any height in the outer zone (Fig. 9).

A significant interaction between zones and heights was present for mites. The cause of this interaction was due to the different density patterns between the 2 zones as the height changed (Fig. 10). The inner zone exhibited a constant increase in mite densities from the lower to the upper heights whereas the outer zone did not exhibit a similar pattern. In both zones the highest densities occurred at the upper height.

No interactions between zones and quadrants or heights and quadrants were found for either eggs or mites. The greatest mean number of eggs was found in the inner south quadrant (Fig. 11). In both the inner and outer zones the greatest numbers of eggs were located in the north and south quadrants. This pattern of more eggs in the north and south quadrants than in the east and west was most pronounced in the outer zone. The greatest mite densities were also found in the north and south quadrants, with more mites in the north than the south quadrant (Fig. 12). The greatest mean number of mites inhabited the inner north quadrant.

A comparison of means for heights and quadrants showed the most eggs to be in the north and south quadrants at all three heights (Fig. 13). The south quadrant contained the

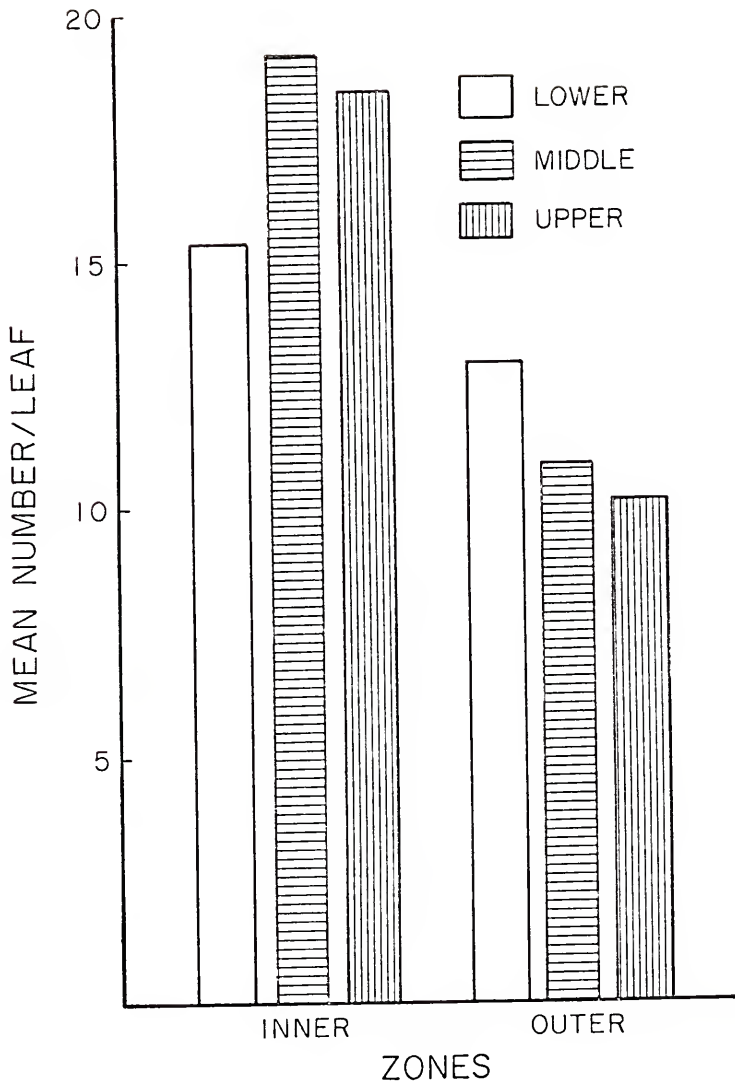


Fig. 9. Mean number of eggs of Oligonychus (Oligonychus) ilicis (McGregor) per leaf in 2 zones and at 3 heights of Ilex crenata 'Hetzii.'

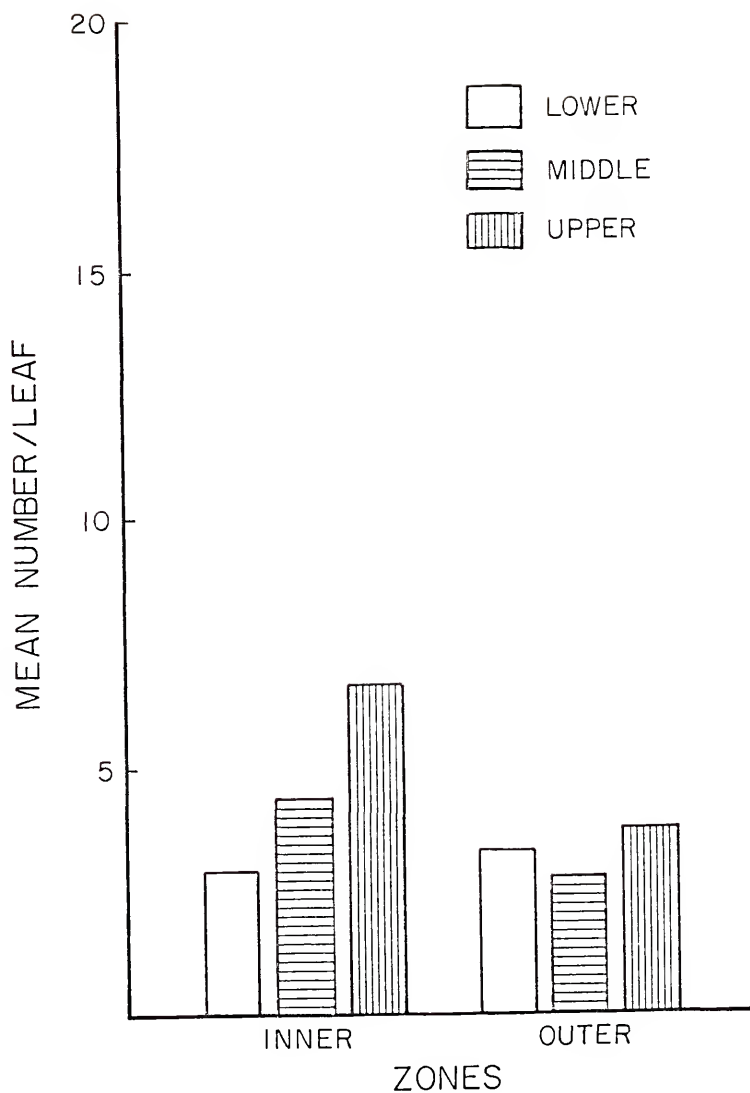


Fig. 10. Mean number of mites, Oligonychus (Oligonychus) ilicis (McGregor), per leaf in 2 zones and at 3 heights of Ilex crenata 'Hetzii.'

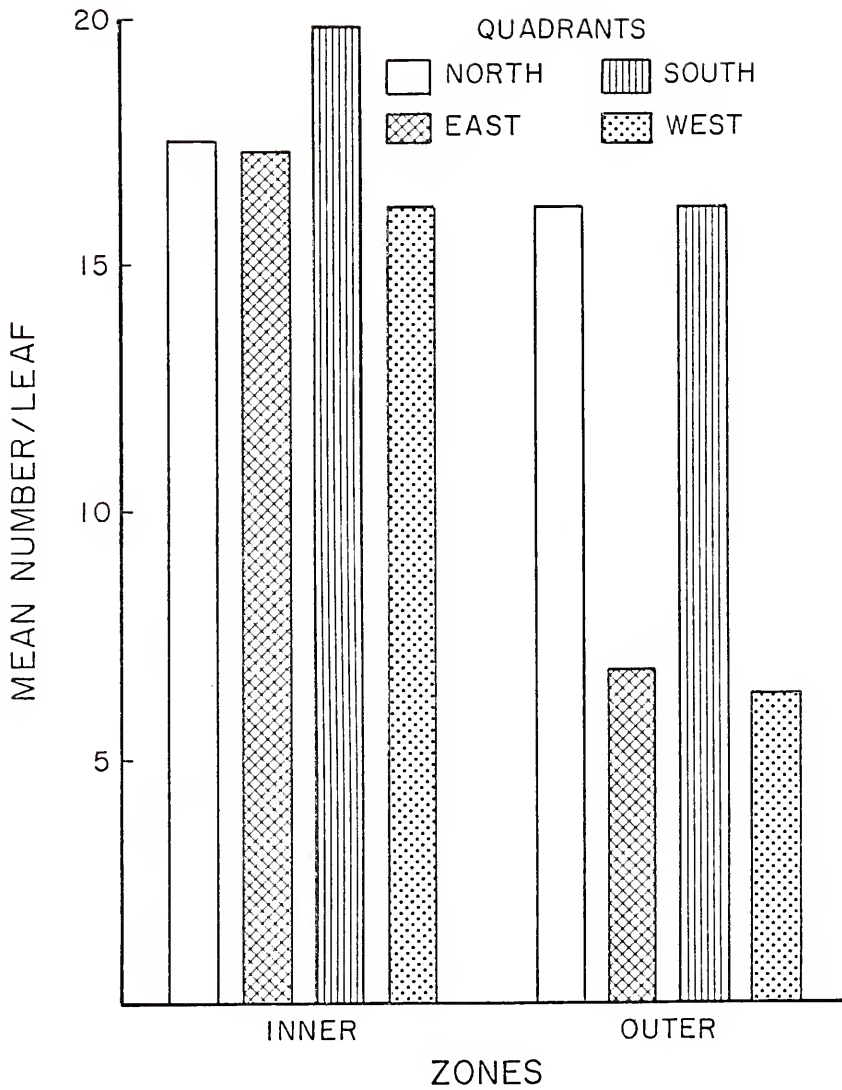


Fig. 11. Mean number of eggs, *Oligonychus* (*Oligonychus*) *ilicis* (McGregor), per leaf in 2 zones and 4 quadrants of *Ilex crenata* 'Hetzii.'

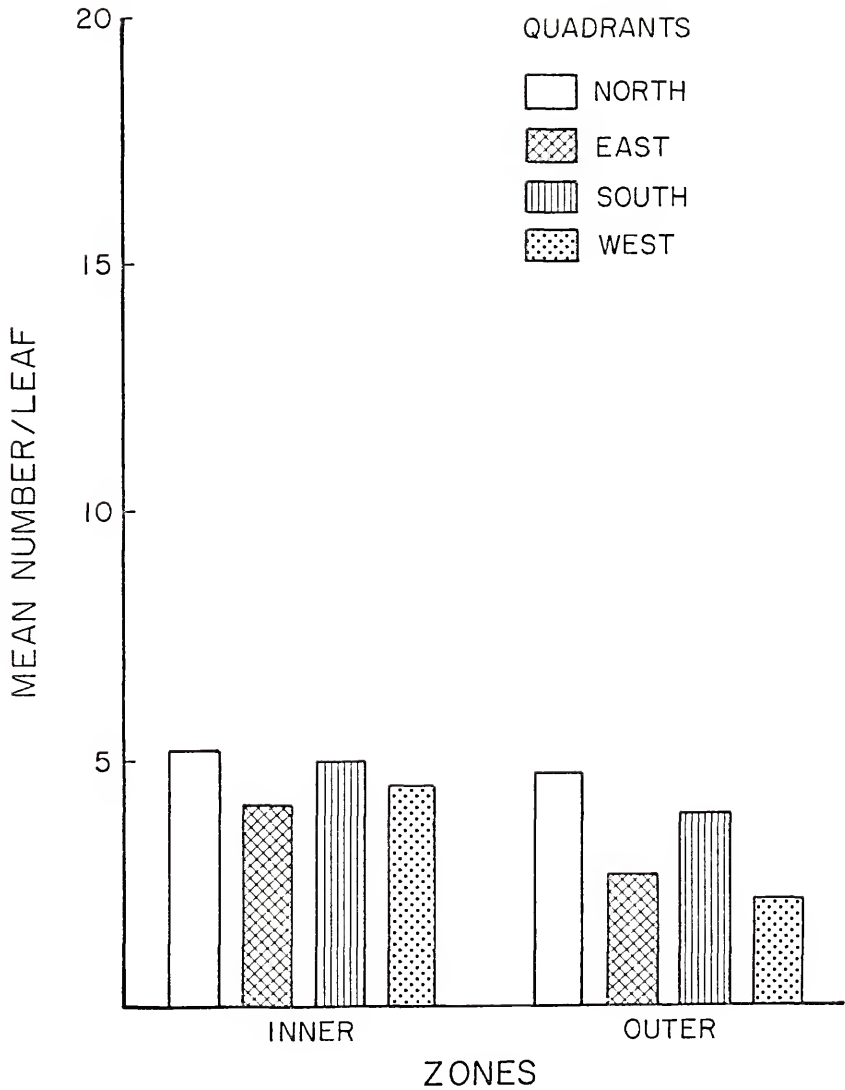


Fig. 12. Mean number of mites, Oligonychus (Oligonychus) ilicis (McGregor), per leaf in 2 zones and 4 quadrants of Ilex crenata 'Hetzii.'

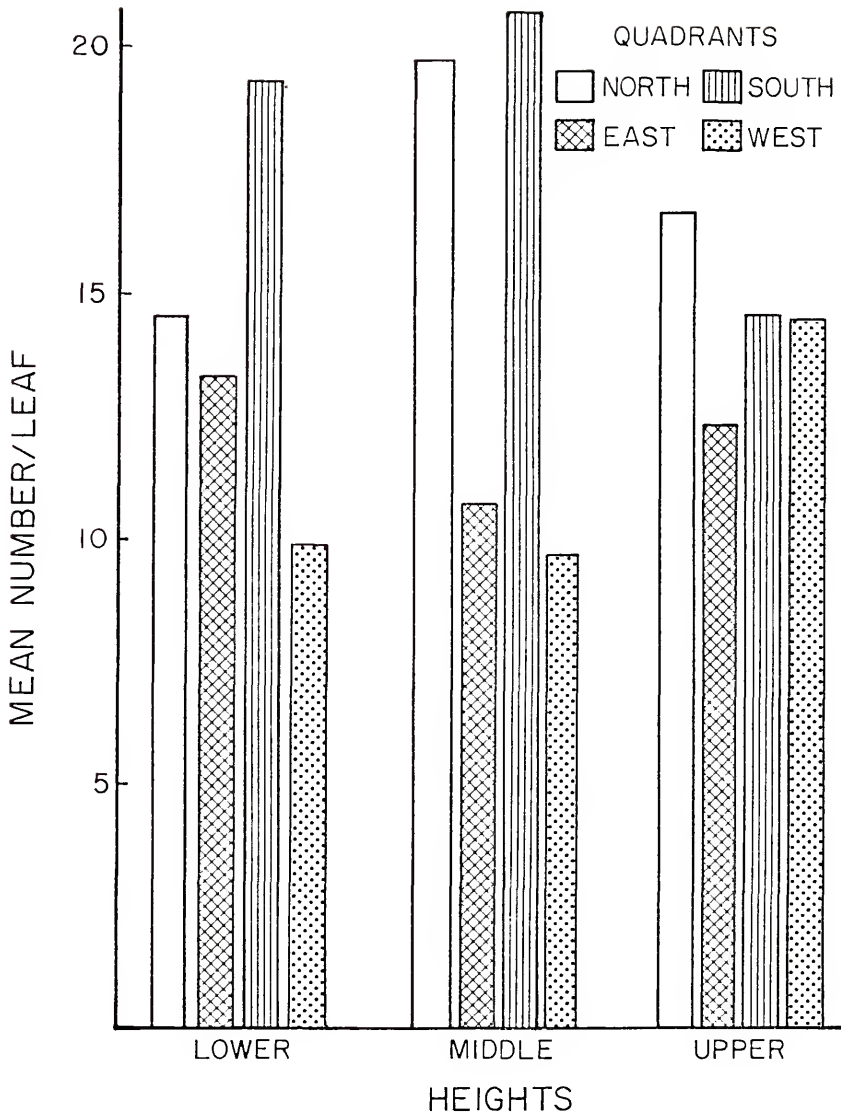


Fig. 13. Mean number of eggs, *Oligonychus* (*Oligonychus*) *ilicis* (McGregor), per leaf at 3 heights and in 4 quadrants of *Ilex crenata* 'Hetzii.'

most eggs at the lower and middle heights, and the north quadrant contained the most eggs at the upper height. Fewest eggs were found in the west quadrant at the lower and middle heights and in the east quadrant at the upper height. The middle south quadrant contained the most eggs. The highest mite densities were found in the upper north quadrant (Fig. 14). At the lower height, more mites were located in the east quadrant which was the only exception to the pattern of more eggs and mites in the north and south quadrants. The pattern for both eggs and mites at the upper height is quite similar.

Significant differences between all possible combinations of zones, heights, and quadrants for eggs and mites were determined (Table 14). The greatest mean number of eggs (23.82) was recorded from the inner, middle, south sampling site, but this did not differ significantly at the 1% level from 19 of the means from other sites. The greatest mean number of mites (7.56) was recorded for the inner, upper, north quadrant, and this value did not differ from 16 other means. The fewest mites were in the outer, middle, west sampling site and the fewest eggs in the outer, middle, east site.

In examining the upper 50% of the means for eggs, the inner zone appears three times more frequently than the outer zone. The middle height composes half of the height designations for eggs, and the south quadrant is found in 5 of the 12 sites. In the upper 50% of the means for

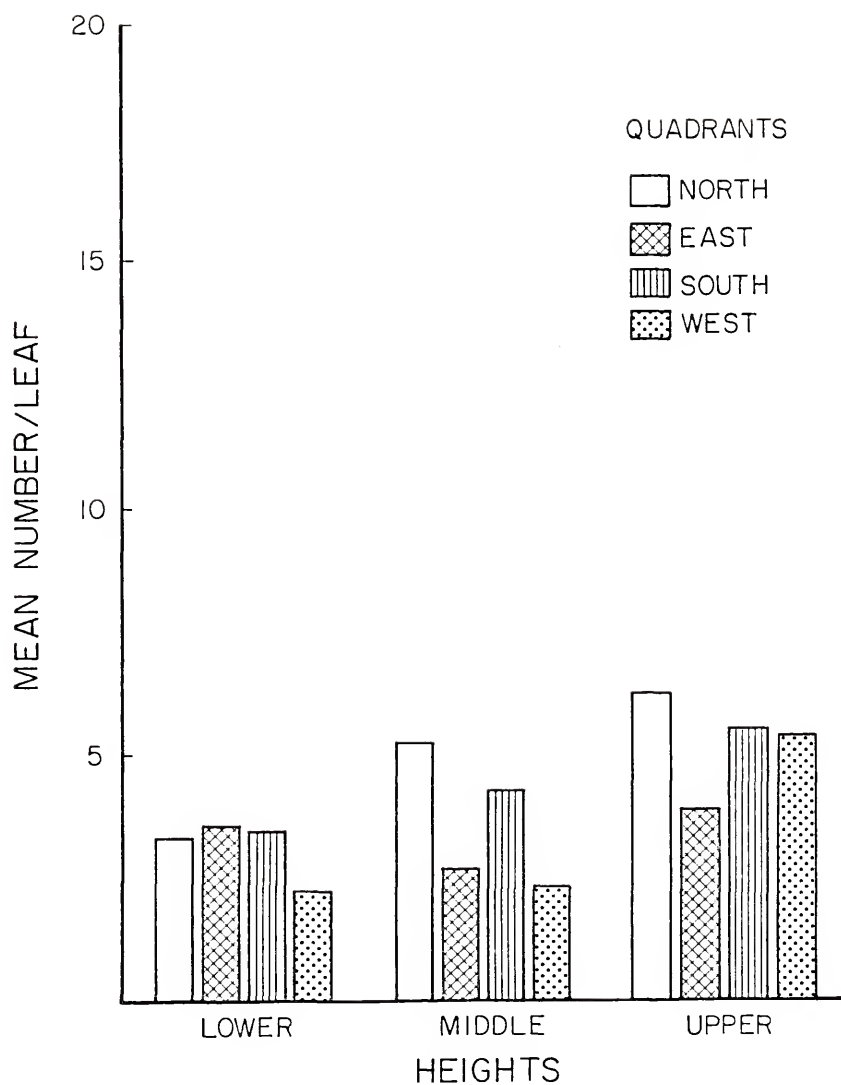


Fig. 14. Mean number of mites, *Oligonychus* (*Oligonychus*) *ilicis* (McGregor), per leaf at 3 heights and in 4 quadrants of *Ilex crenata* 'Hetzii.'

Table 14. Mean number of eggs and mites, Oligonychus (Oligonychus) ilicis (McGregor), in each of 24 sampling sites on Ilex crenata 'Hetzii.'

Location ¹	Eggs ²	Location	Mites
IMS	23.82 a	IUN	7.56 a
OMN	21.31 a b	IUS	7.36 a b
OLS	20.50 a b	IUW	7.26 a b c
IUN	19.89 a b	OMN	5.34 a b c d
IUW	19.52 a b	IMN	5.22 a b c d
IME	19.36 a b	OUN	5.02 a b c d
IUS	17.95 a b c	IUE	4.86 a b c d
IMN	17.92 a b c	IMS	4.66 a b c d
ILS	17.91 a b c	IME	4.14 a b c d
OMS	17.31 a b c	OLS	4.00 a b c d
IUE	16.82 a b c d	OMS	3.94 a b c d
IMW	16.01 a b c d	OLN	3.82 a b c d
ILE	15.83 a b c d	OUS	3.80 a b c d
ILN	14.88 a b c d	OLE	3.77 a b c d
OLN	14.17 a b c d	OUW	3.68 a b c d
OUN	13.23 a b c d	IMW	3.63 a b c d
ILW	13.11 a b c d	ILE	3.26 a b c d
OUS	10.95 a b c d	OUE	2.97 b c d
OLE	10.80 a b c d	ILS	2.95 b c d
OUW	9.24 a b c d	ILN	2.89 c d
OUE	7.70 b c d	ILW	2.52 d
OLW	6.59 b c d	OLW	1.93 d
OMW	3.26 c d	OME	1.26 d
OME	2.01 d	OMW	0.97 d

¹I = Inner, O = Outer, L = Lower, M = Middle, U = Upper, N = North, S = South, E = East, W = West.

²Means followed by the same letter are not significantly different at the 1% level by Duncan's multiple range test.

mites, the inner zone appears 7 times, the upper and middle heights appear 5 times each, and either the north or south quadrants appear 9 times.

Conclusion

Southern red mites were found predominantly on the under surface of I. crenata 'Hetzii' leaves. The mean number of mites in the upper portion of the plant differed significantly at the 1% level from the means for the lower and middle heights of the holly plants. Means for eggs did not differ with regard to height. Significant differences for zones existed for both eggs and mites, with more eggs and mites being located in the inner zone. Direction also influenced egg numbers with the most eggs and mites being found in the north and south quadrants.

Under the conditions of this study, the optimum sampling location on I. crenata 'Hetzii' would be in the inner zone and at the upper height in either the north or south quadrants.

EVALUATION OF FOUR ACARICIDES AND COMBINATIONS FOR
CONTROL OF SOUTHERN RED MITE ON
Ilex crenata 'Hetzii'

Introduction

The southern red mite, Oligonychus (Oligonychus) ilicis (McGregor), usually attacks the lower leaf surface of woody ornamental plants, causing a graying or mesophyll collapse, "firing," and defoliation (Denmark, 1968). Oligonychus (O.) ilicis is particularly a pest of azaleas, camellias, and holly.

For several years southern red mites have severely infested field-grown holly, Ilex crenata 'Hetzii,' in a nursery near Macclenny, Florida. In the past some measure of control was achieved by routine sprays with mixtures containing parathion, ethion and oil, dicofol, or oxydemetonmethyl. Five or more applications were made from January to April each year (Poe et al., 1976a). Since the holly plants must remain in the field for several years before reaching saleable size, the grower incurs considerable cost in controlling mites. The need exists for an effective residual compound so costs can be lowered by reducing the number of acaricide applications.

The objective of this study was to evaluate four acaricides, naled, dicofol, propargite, hexakis, and

combinations of these materials at reduced rates for control of O. (O.) ilicis.

Literature Review

Sulfur was essentially the only compound used for mite control until about 1920. It is still widely employed for control of many susceptible tetranychid species in the genera Eotetranychus, Eutetranychus, and Oligonychus. Sulfur applications, with few exceptions, do not readily control spider mites in the genera Tetranychus and Panonychus (Jeppson et al., 1975).

Several researchers have studied the effects of a number of pesticides on O. (O.) ilicis infesting ornamental plants and coffee. Matthyse and Naegele (1950) treated southern red mite infested azaleas, Rhododendron sp., with chlorfenethol, ovex, parathion, Dow Pestox C-1014 (63.3% technical octamethyl pyrophosphoramide), EPN, USI T 313 (2 gm piperonyl cyclonene, 0.2 gm pyrethrins, 1 gm rotenone per 100 ml), and dieldrin. Chlorfenethol produced quick kill and good residual activity for 1-1/2 months. Ovex required two weeks to diminish the population to a low level, where it remained. Parathion (one pound of 25% per 100 gal water) gave quick kill but only one week's residual action. Treatments with Dow Pestox C-1014 exhibited complete kill within 24 hours but showed little residual action. EPN gave slower kill but populations had still not reached their original levels after 1-1/2 months.

after 1-1/2 months. Mites treated with USI T 313 died rapidly. This combination of synergized rotenone and pyrethrins gave about 2 weeks residual action, but mite populations rose rapidly beyond this time. Dieldrin provided no control of O. (O.) ilicis. Chlorfenethol was the most effective compound tested in terms of quick kill and long residual activity.

Additional treatments with other toxicants were conducted by Matthyse and Naegele (1952) for control of O. (O.) ilicis on azalea, Rhododendron sp., and American holly, Ilex opaca Ait. Of the compounds tested a single application of TM-2 50% WP (p-chlorophenyl p-chlorobenzene sulphonate) consistently gave long residual action preventing mite build-up for at least 45 days on azalea and 56 days on American holly. EPN was included in only the holly experiment but provided excellent residual action for 60 days.

Calsa and Sauer (1952) reported control measures for O. (O.) ilicis on coffee in Brazil. Plant condition influenced the amount of damage inflicted by the mites; healthier plants sustained less damage. Also larger populations of mites were observed on plants treated for other pests, and attack of the southern red mite coincided with the attack of a leafminer. As a result, acaricides and insecticides were applied together. Sulfur (40%) or parathion was applied for mite control along with benzene hexachloride (1.5 to 2% gamma isomer) for leafminer control.

Pesticides had to be applied at the beginning of an infestation to prevent damage as control was difficult to achieve if mite populations were allowed to build up to a high level.

In 1969, the University of Florida, IFAS, Department of Entomology and Nematology recommended chlorobenzilate, dicofol, tetradifon, and a mixture of ethion and oil emulsion for southern red mite control (Denmark, 1968).

Wilson and Oliver (1969) evaluated seven EC formulation acaricides for control of southern red mites on dwarf holly, Ilex compacta, and azaleas, Rhododendron sp. At a rate of 1/2 lb per acre only partial control of mites on dwarf holly was achieved with all compounds, chloropropylate, bromopropylate, chlorobenzilate, methidathion, chlordimeform, and tetradifon. A general increase in the mite population was noted in all treatments from the first to the last examination with the exception of tetradifon for which there was a noticeable decrease in mite number. The authors felt that a higher rate of application would provide better control. The population of O. (O.) ilicis on azaleas was most effectively reduced by bromopropylate. Chlorobenzilate and tetradifon did not significantly reduce the southern red mite population.

Poe et al. (1976a) sprayed mite infested holly, I. crenata 'Hetzii,' with 6 contact acaricides and found cyhexatin to reduce the initial population greatly and provide good residual control for five to seven weeks. Chlorobenzilate 4EC and a mixture of trichlorfon and

oxydemetonmethyl provided control almost as good as that of cyhexatin until after the fifth week. Methiocarb at two rates and propargite were not as effective in controlling O. (O.) ilicis as the other compounds tested.

Granular systemic pesticides were also evaluated by Poe et al. (1976b) for control of southern red mites on I. crenata 'Hetzii.' Field conditions were not ideal for the application of granular materials. Plants were dormant and no precipitation occurred for a month after chemicals were applied, and there was no means of irrigation. Therefore, the data were inconclusive for use of 10G formulations of carbofuran, aldicarb, oxamyl L, and terbufos for O. (O.) ilicis control.

Methods and Materials

In late November and December 1978, four acaricides and combinations of reduced rates of these materials were evaluated for control of southern red mites on holly, I. crenata 'Hetzii,' grown near Macclenny, Florida. The acaricidal compounds tested were dicofol 1.6 EC (4,4'-dichloro-a-(tri=chloromethyl)benzhydrol), hexakis 50 WP (hexakis (β,β -dimethyl=phenethyl)distanoxane), naled 8 EC (1,2-dibromo-2,2-dichloroethyl dimethyl phosphate), and propargite 30 WP (2-(p-tert-butylphenoxy) cyclohexyl 2-propynyl sulfite).

The acaricides were applied with two 1-gal compressed-air hand sprayers. Each plant was sprayed until runoff

occurred. The rates are given in Table 15. Spreader-sticker, Ortho X-77 (4.5 ml/gal), was included in each treatment. The check plots were sprayed with water and spreader-sticker.

Each treatment was replicated 4 times in a randomized block design. Each replicate consisted of 3 to 5 plants, but only one plant within a replicate was sampled; the other plants served as a buffer between treatments. The plants sampled were marked with a stake and flag so they were easily identified for sampling on each date. Twigs were taken from 24 sites on each plant. Each sample consisted of 3 leaves, and sampling sites were selected from lower, middle, and upper heights and from outer and inner zones of the plant. Samples from these 3 heights and 2 zones were further divided to represent the north, south, east, and west quadrants of the holly plants.

Samples were taken 1 day before treatment and on 7, 14, and 21 days after treatment. Leaves were examined under a dissecting microscope and numbers of eggs and mites were recorded.

Data were analyzed by analysis of variance and Duncan's multiple range test.

Results and Discussion

All materials tested resulted in a decrease in the mean number of eggs observed at 1 and 2 weeks after treatment (Table 16). Except for the naled (N), propargite (P)

Table 15. Rates of 4 acaricides and combinations applied to Ilex crenata 'Hetzii' for control of Oligonychus (Oligonychus) ilicis (McGregor).

Acaricide	Formulation	Rate ai/A
Check	--	--
Hexakis (H)	50WP	0.75
Propargite (P)	30WP	0.50
Dicofol (D)	1.6EC	1.00
Naled (N)	8EC	0.50
H+P		0.37+0.25
H+D		0.37+0.50
H+N		0.37+0.25
P+D		0.25+0.50
P+N		0.25+0.25
D+N		0.50+0.25
H+P+D		0.25+0.17+0.33
H+P+N		0.25+0.17+0.17
H+D+N		0.25+0.50+0.17
P+D+N		0.17+0.33+0.17
H+P+D+N		0.19+0.12+0.25+0.12

Table 16. Mean number of southern red mite eggs, Oligonychus (Oligonychus) ilicis (McGregor), per leaf before and after treatment of Ilex crenata 'Hetzii' with selected acaricides.

Acaricide	Pretreatment	Posttreatment (weeks)		
		1	2	3
Check	13.39	9.83	8.91	7.42
Hexakis (H)	6.54	5.62	4.80	1.75
Propargite (P)	10.87	7.09	4.86	2.28
Dicofol (D)	11.13	6.33	3.76	2.61
Naled (N)	10.17	8.64	5.60	9.32
H+P	7.80	5.80	4.44	2.40
H+D	12.88	9.83	7.05	4.06
H+N	11.41	6.42	4.90	2.21
P+D	10.41	7.49	6.02	6.08
P+N	13.31	7.00	5.70	6.02
D+N	13.27	10.43	7.17	7.07
H+P+D	8.89	8.05	5.81	3.40
H+P+N	11.01	5.68	3.86	1.92
H+D+N	9.55	6.42	4.50	3.30
P+D+N	10.33	8.97	7.94	4.40
H+P+D+N	7.99	5.48	5.00	2.79

plus dicofol (D), and P+N treated plants, a decrease was noted at 3 weeks post treatment. The check plots also showed a decrease, but not as marked as those receiving the acaricide treatments. The viability of eggs on treated plants could not be determined by visual methods so all eggs present on the leaves were recorded. It is possible that many of the eggs observed would not have hatched.

With all treatments except those of N and D+N, mite numbers decreased each week after treatment (Table 17). The naled plots showed increases in the second and third weeks after treatment. The D+N plots exhibited an increase from the first to the second week but a decrease from the second to the third week. By the third week, the following acaricides and combinations had reduced the mite population to zero: hexakis (H); H+P; H+D; H+P+D; H+P+N; P+D+N; and H+P+D+N. Hexakis was the only product that reduced populations to zero when used alone. All combinations that included hexakis, except one, reduced populations to zero.

Based on pretreatment counts the data were transformed to percent eggs and mites remaining on leaves at 1, 2, and 3 weeks after treatment. After 1 week the greatest percentage of eggs remaining on leaves was in the plots treated with H+P+D (Table 18). The lowest percentage of eggs remaining at the end of 1 week was in the H+P+N plots. One week after treatment the H+P+D plots had a significantly higher percentage of eggs remaining than the P, D, H+N, P+N, and H+P+N treated plots. However, none of the

Table 17. Mean number of southern red mites, Oligonychus (Oligonychus) ilicis (McGregor), per leaf before and after treatment of Ilex crenata 'Hetzii' with selected acaricides.

Acaricide	Pretreatment	Posttreatment (weeks)		
		1	2	3
Check	5.27	2.04	1.85	1.39
Hexakis (H)	1.93	0.24	0.01	0.00
Propargite (P)	3.92	1.94	1.08	0.25
Dicofol (D)	4.44	0.55	0.20	0.06
Naled (N)	4.10	1.36	1.77	2.05
H+P	2.36	0.14	0.00	0.00
H+D	4.45	0.65	0.02	0.00
H+N	2.69	0.23	0.01	0.01
P+D	4.50	1.13	1.21	0.46
P+N	4.72	0.82	0.70	0.57
D+N	5.04	1.27	1.37	1.16
H+P+D	3.06	0.27	0.02	0.00
H+P+N	3.44	0.47	0.01	0.00
H+D+N	4.19	1.00	1.19	0.43
P+D+N	4.40	0.61	0.06	0.00
H+P+D+N	2.19	0.25	0.05	0.00

Table 18. Percent southern red mite eggs, Oligonychus (Oligonychus) ilicis (McGregor), remaining on Ilex crenata 'Hetzii' at 1, 2, and 3 weeks after treatment with selected acaricides.¹

Acaricide	Posttreatment (weeks)		
	1	2	3
Check	73.4 abcd	66.5 abc	55.4 bc
Hexakis (H)	85.9 ab	73.4 ab	26.8 ef
Propargite (P)	65.2 bcd	44.7 cd	21.0 ef
Dicofol (D)	56.9 cd	33.8 d	23.5 ef
Naled (N)	80.7 abc	52.3 bcd	87.0 a
H+P	74.4 abcd	56.9 abcd	30.8 def
H+D	76.3 abcd	54.7 abcd	31.5 def
H+N	56.3 cd	42.9 cd	19.4 f
P+D	72.0 abcd	57.8 abcd	58.4 b
P+N	52.6 d	42.8 cd	45.2 bcd
D+N	78.6 abc	54.0 abcd	53.3 bc
H+P+D	90.6 a	65.4 abc	38.2 cde
H+P+N	51.6 d	35.1 d	17.4 f
H+D+N	67.2 abcd	47.1 cd	34.6 def
P+D+N	86.8 ab	76.9 a	39.1 cde
H+P+D+N	68.6 abcd	62.6 abc	34.9 def

¹Percents in the same column and followed by the same letter are not significantly different (1% level) as determined by Duncan's multiple range test.

acaricides either individually or in combination reduced egg numbers significantly from the check. Two weeks after treatment the highest percentage of eggs remaining was in the P+D+N treated plots followed by hexakis and the check plots. Dicofol treated plots had the lowest percentage of eggs. Three weeks after treatment, naled plots had a significantly greater percentage of eggs than all other treatments; the lowest percentage was recorded from H+P+N treatments. At 1 week after treatment, as with 2 and 3 weeks, the viability of eggs could not be determined by visual observation. Therefore, the effectiveness of treatments with regard to percentage of eggs remaining is questionable.

One week after treatment the highest percentage of mites was found in the H+P plot (Table 19); this differed significantly from all treatments except propargite. The lowest percentage of mites remaining occurred in the H+N treatments. Two weeks after treatment the highest percentage of mites remaining was in the naled plots, which did not differ significantly from the check, H+D+N, P, D+N, or P+D treatments. The lowest percent remaining was found in the H+P plots. In a study by Poe et al. (1978) using the same chemicals, two weeks after treatment the percent reduction of mites was also greatest in the H+P treated plots. Three weeks following spray applications the naled plots showed a significantly greater percentage of mites remaining than did all other treatments. The check plot had the next highest percentage. All except one of the 7 treatments with zero percent mites

Table 19. Percent southern red mites, Oligonychus (Oligonychus) ilicis (McGregor), remaining on Ilex crenata 'Hetzii' at 1, 2, and 3 weeks after treatment with selected acaricides.

Acaricide	Posttreatment (weeks)		
	1	2	3
Check	38.7 bc	35.1 ab	26.4 b
Hexakis (H)	12.4 de	0.5 c	0.0 d
Propargite (P)	49.5 ab	27.6 ab	6.4 cd
Dicofol (D)	12.4 de	4.5 c	1.4 d
Naled (N)	33.1 c	43.2 a	50.0 a
H+P	59.3 a	0.0 c	0.0 d
H+D	14.6 de	0.4 c	0.0 d
H+N	8.6 e	0.4 c	0.4 d
P+D	25.1 cd	26.9 ab	10.2 bcd
P+N	17.4 de	14.8 bc	12.1 bcd
D+N	25.2 cd	27.2 ab	23.0 bc
H+P+D	8.8 e	0.7 c	0.0 d
H+P+N	13.7 de	0.3 c	0.0 d
H+D+N	23.9 cde	28.4 ab	10.3 bcd
P+D+N	13.9 de	1.4 c	0.0 d
H+P+D+N	11.4 de	2.3 c	0.0 d

¹Percents in the same column and followed by the same letter are not significantly different (1% level) as determined by Duncan's multiple range test.

remaining contained hexakis. The only treatments containing hexakis which did not drop to zero were H+D+N and H+N.

When compounds were applied singly, propargite was most effective in reducing eggs after 3 weeks; naled was least effective (Table 18). In combinations of two compounds, H+N was most effective after 3 weeks. In combinations of three compounds, H+P+N was most effective. Why naled was least effective alone but did give good residual control in combinations is not fully understood. Probably hexakis was providing most of the control.

Hexakis provided the best control of mites after 3 weeks when used alone (Table 19). Poe et al. (1978) reported that propargite treated plants had the lowest percentage (4.4) of mites remaining at the end of 2 weeks followed by hexakis (5.8); no data were available for three weeks after treatment. Naled exhibited the least control (Table 19). In combinations of two, H+P and H+D were equally good and were comparable to hexakis used alone. Combinations of H+P+D, H+P+N, P+D+N, and H+P+D+N were not significantly different from hexakis or H+P and H+D.

In summary, of the compounds sprayed singly, hexakis provided the best control of southern red mites at 3 weeks after application. Combinations of compounds offering residual action equal to that of hexakis were H+P, H+D, H+P+D, H+P+N, P+D+N, and H+P+D+N.

GENERAL SUMMARY

The net reproductive rate and intrinsic rate of natural increase were greatest at 26.5°C when southern red mites were reared at constant temperatures. These values decreased at both lower and higher temperatures. The greatest potential for heavy mite populations therefore exists during warmer periods during late fall, winter, and early spring. The effects of fluctuating temperatures on these and other parameters should be investigated as widely fluctuating temperatures are often experienced under field conditions.

Knowledge of the preferred living site of O. (O.) ilicis can reduce the number of samples taken to determine population levels and the need for chemical treatment. Southern red mites were found in greatest numbers in the inner zone and at the upper height of the north and south quadrants. Ideally, studies similar to the one reported here should be continued from October through May to determine if there are seasonal changes in the mites' distributional patterns.

The cost of control of southern red mites can be reduced by using compounds or combinations of compounds which provide residual action. Hexakis sprayed singly and

combinations at reduced rates of hexakis and propargite, hexakis and dicofol, hexakis and propargite and dicofol, hexakis and propargite and naled, propargite and dicofol and naled, and hexakis and propargite and dicofol and naled gave good residual action 3 weeks after application. Plots were not sampled beyond 3 weeks after treatment. Future research could determine the time required for mite populations to reach pretreatment levels again. Since spider mites can rapidly develop resistance to acaricides, studies of continued exposure of O. (O.) ilicis to these toxicants could provide valuable information about the length of time these acaricides will provide control before resistance develops when used singly or in combinations at reduced rates.

BIBLIOGRAPHY

- Akita, Y. 1971. Biological studies of the common conifer spider mite, Oligonychus ununguis Jacobi (Acarina: Tetranychidae). Bull. Gov. For. Exp. Stn. No. 236. 1-25.
- Albrigo, L. G., and C. W. McCoy. 1974. Characteristic injury by citrus rust mite to orange leaves and fruit. Proc. Fla. State Hort. Soc. 87:48-55.
- Allen, J. C., and C. W. McCoy. 1979. The thermal environment of the citrus rust mite. Agric. Meteorol. 20: 411-425.
- Baker, E. W., and A. E. Pritchard. 1953. A guide to the spider mites of cotton. Hilgardia 22(7):203-234.
- Banerjee, B. 1975. A demographic study of the growth rate of the red spider mite Oligonychus coffeae (Nietner) on two varieties of tea. Acarologia 16(3):428-435.
- Broadbent, L. 1948. Methods of recording aphid populations for use in research on potato virus diseases. Ann. Appl. Biol. 35:551-566.
- Butler, G. D., Jr., and M. K. Abid. 1965. The biology of Oligonychus platani on pyracantha. J. Econ. Entomol. 58(4):687-688.
- Calsa, R., and H. F. G. Sauer. 1952. The red spider of coffeae plantations. Biologico 18:201-208.
- Das, G. M. 1959. Bionomics of the tea red spider, Oligonychus coffeae (Nietner). Bull. Entomol. Res. 50(2):265-274.
- Das, G. M., and S. C. Das. 1967. Effect of temperature and humidity on the development of tea red spider mite, Oligonychus coffeae (Nietner). Bull. Entomol. Res. 57(3):433-436.
- Dean, H. A. 1959. Quadrant distribution of mites on leaves of Texas grapefruit. J. Econ. Entomol. 52(4):725-727.

- Denmark, H. A. 1968. The southern red mite, Oligonychus ilicis (McGregor). Fla. Dept. Agric. Div. Plant Industry Entomol. Cir. 79. 1 p.
- Div. Plant Industry Records. Fla. Dept. Agric., Gainesville, Fla.
- Ebeling, W. 1959. Subtropical fruit pests. Univ. Calif. Div. Agric. Sci., Los Angeles. 436 pp.
- Ehara, S. 1963. A new mite of Oligonychus from rice, with notes on some Japanese spider mites (Acarina: Tetranychidae). Jap. J. Appl. Entomol. Zool. 7(3): 228-231.
- Elmer, H. S. 1965. Banks grass mite, Oligonychus pratensis, on dates in California. J. Econ. Entomol. 58(3):531-534.
- Feese, H., and G. Wilde. 1977. Factors affecting survival and reproduction of the Banks grass mite, Oligonychus pratensis. Environ. Entomol. 6(1):53-56.
- Friedrick, G. 1951. Über die durch der Wind bedingte ungleiche Verteilung von Schildläusen und Wintereiern der Insekten an den Zweigen der Obstbäume. Anz. Schädlingk. 24:33-34.
- Garman, P. 1923. Notes on the life history of the spruce mite Paratetranychus ununguis (Jacobi). Conn. Agric. Exp. Stn. Bull. 247:340-342.
- Gupta, S. K., M. S. Dhooria, and A. S. Sidhu. 1975. Effect of food and temperature on the development, longevity, and fecundity of sugarcane red spider mite, Oligonychus indicus (Hirst). Acarologia 16(3):436-440.
- Hu, C. C., and L. C. Wang. 1965. A study of the annual life cycle of the tea red spider mite, Oligonychus coffeae (Nietner). J. Agric. Assoc. China 50:1-14.
- Hudson, M., and E. J. LeRoux. 1961. Variation between samples of immature stages, and mortalities from some factors, of the European corn borer, Ostrinia nubilalis (Hübner) (Lepidoptera: Pyralidae) on sweet corn in Quebec. Can. Entomol. 93:867-888.
- Hutson, R. 1933. Experiments on the control of mites infesting raspberries. J. Econ. Entomol. 26:425-430.
- Jeppson, L. R., H. H. Keifer, and E. W. Baker. 1975. Mites injurious to economic plants. Univ. Calif. Press, Berkeley. 614 pp.

- Keifer, H. H. 1935. Report on systematic entomology.
Calif. State Dept. Agric. Monthly Bull. 24:427-430.
- Koehler, C. S., and G. W. Frankie. 1968. Distribution and seasonal abundance of Oligonychus subnudus on Monterey pine. Ann. Entomol. Soc. Am. 61(6):1500-1506.
- Krantz, G. W. 1978. A manual of acarology, 2nd ed.
Oregon State Univ. Book Stores, Inc., Corvallis.
509 pp.
- Kremer, F. W. 1956. Studies on the biology, epidemiology, and control of Bryobia praetiosa Koch. Höfchenbriefe 9(4):189-256.
- Laing, J. E. 1969. Life history and life table of Tetranychus urticae Koch. Acarologia 11(1):32-42.
- Löyttyniemi, K. 1970. Zur Biologie der Nadelholzspinnmilbe (Oligonychus ununguis (Jacobi), Acarina, Tetranychidae) in Finnland. Acta Entomol. Ennica 1-64.
- MacLellen, C. R. 1962. Mortality of codling moth eggs and young larvae in an integrated control orchard. Can. Entomol. 94:655-666.
- Malcolm, D. R. 1955. Biology and control of the timothy mite, Paratetranychus pratensis (Banks). Wash. Agric. Exp. Stn. Tech. Bull. 17. 35 pp.
- Matthysse, J. G., and J. A. Naegele. 1950. Mites on woody plants and their control. Proc. 26th National Shade Tree Conf. 26:78-90.
- Matthysse, J. G., and J. A. Naegele. 1952. Spruce mite and southern red mite control experiments. J. Econ. Entomol. 45(3):383-387.
- McCoy, C. W., and L. G. Albrigo. 1975. Feeding injury to the orange caused by the citrus rust mite, Phyllocoptruta oleivora (Prostigmata: Eriophyoidea). Ann. Entomol. Soc. Am. 68:289-297.
- McGregor, E. A. 1917. Descriptions of seven new species of red spiders. Proc. U. S. Nat. Mus. 51:581-590.
- McGregor, E. A. 1931. A new spinning mite attacking raspberry in Michigan. Proc. Entomol. Soc. Wash. 33:134-193.
- McGregor, E. A. 1941. The avocado mite of California, a new species. Entomol. Soc. Wash. Proc. 43:85-88.

- McKenzie, H. L. 1935. Biology and control of avocado insects and mites. Calif. Agric. Exp. Stn. Bull. 592:1-48.
- McMurtry, J. A., and H. G. Johnson. 1966. An ecological study of the spider mite Oligonychus punicae (Hirst) and its natural enemies. Hilgardia 37(11):363-402.
- Miller, A. E. 1925. An introductory study of the Acarina or mites of Ohio. Ohio Agric. Exp. Stn. Bull. 386: 85-172.
- Misra, B. C., and P. Israel. 1968. Studies on the bionomics of paddy mite. Oligonychus oryzae (Hirst) (Acarina Tetranychidae). Oryza J. Assoc. Rice. Res. Workers 5(1):32-37.
- Mohamed, I. I. 1963. Acarine mites occurring on cotton plants in Egypt. Bull. Soc. Entomol. Egypte 46:511.
- Morris, R. E. 1955. The development of sampling techniques for forest insect defoliators with particular reference to the spruce budworm. Can. J. Zool. 33:225-294.
- Moutia, L. A. 1958. Contribution to the study of some phytophagous acarina and their predators in Mauritius. Bull. Entomol. Res. 49:59-75.
- Muma, M. H. 1970. Preliminary studies of environmental manipulation to control injurious insects and mites in Florida citrus groves. Proc. Tall Timbers Conf. Ecol. Anim. Control by Habitat Management 2:23-40.
- Paradis, R. O., and E. J. LeRoux. 1962. A sampling technique for population and mortality factors of the fruit-tree leaf roller, Archips argyrospilus (Wlk.) (Lepidoptera: Tortricidae), on apple in Quebec. Can. Entomol. 94:561-573.
- Pierce, W. C. 1953. Studies of mites and their control on pecan in Louisiana. J. Econ. Entomol. 46(4):561-565.
- Poe, S. L., G. H. Childs, and J. A. Cornell. 1978. Acaricide combinations for control of Oligonychus ilicis on Ilex crenata var. Hetzii. South. Nurserymen's Assoc. Res. Conf. 23:70-71.
- Poe, S. L., H. Collins, and C. Shih. 1976a. Numeric response of Oligonychus ilicis to contact acaricides. South. Nurserymen's Res. Conf. 3:39-40.

- Poe, S. L., H. Collins, and C. Shih. 1976b. Effect of systemic pesticides on the southern red mite on Ilex crenata var. Hetzii. South. Nurserymen's Res. Conf. 21:41-42.
- Reeves, R. M. 1963. Tetranychidae infesting woody plants in New York State, and a life history study of the elm spider mite, Eotetranychus matthyssei n. sp. Cornell Univ. Agric. Exp. Stn. Mem. 380. 99 pp.
- Smith, R. H. 1939. Observations on the ilicis mite, Paratetranychus ilicis (McGregor). Bull. Calif. Dept. Agric. 28(3):240-242.
- Southwood, T. R. E. 1978. Ecological methods. John Wiley & Sons, Inc., New York. 524 pp.
- Tan, F. M., and C. R. Ward. 1977. Laboratory studies on the biology of the banks grass mite. Ann. Entomol. Soc. Am. 70(4):534-536.
- Tanigoshi, L. K., and J. A. Logan. 1979. Tetranychid development under variable temperature regimes. Pages 165-175 in J. G. Rodriguez, ed. Recent advances in acarology 1. Academic Press, New York.
- Thewke, S. E., and W. R. Enns. 1969. The spider mite complex (Acarina: Tetranychoida) in Missouri. Univ. Missouri Mus. Contrib. Monogr. 1. 106 pp.
- van Brussel, E. W. 1975. Interrelations between citrus rust mite, Hirsutella thompsonii and greasy spot on citrus in Surinam. De Surinaamse Landbouw 23(3): 119-121.
- Wilson, N. L., and A. D. Oliver. 1969. Evaluation of some acaricides for control of spider mites on three woody ornamentals in Louisiana. J. Econ. Entomol. 62(6):1400-1401.
- Yothers, W. W., and A. C. Mason. 1930. The citrus rust mite and its control. U. S. Dept. Agric. Tech. Bull. 176.
- Zaher, M. A., and K. K. Shehata. 1971. Biology of the red spider mite Oligonychus mangiferus (R. and S.). Bull. Soc. Entomol. Egypte 55:393-401.

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I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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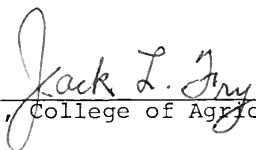
I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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